ENHANCING THE COMPANY'S FINANCIAL PERFORMANCE THROUGH MANAGING THE PERFORMANCE OF SUPPLY CHAIN OPERATIONS:

A CASE STUDY OF AN EGYPTIAN MANUFACTURING COMPANY

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This thesis is dedicated to my daughter, Fatma, who spent many times with family to allow me to work on my research. I am deeply sorry for the time we spent away from each other.

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ABSTRACT

A limited number of studies have been conducted to demonstrate the potential impact of managing supply chain (SC) day-to-day practices on improving a company's financial performance. Previous research in this area has often failed to develop a fully integrated performance measurement framework which captures the critical link between SC performance and overall business performance. The inability to describe the applied methodology in detail, to cover all business dimensions and to incorporate different levels of decision making were factors found to limit the impact of these frameworks on enhancing organisations performance. This research proposes a procedure to align SC operational strategy to a company's financial strategy in the manufacturing sector through developing a framework linking SC operations' performance to the company's strategic financial objectives.

A SCOR FAHP technique is proposed combining the Supply Chain Operation Reference (SCOR) model and the fuzzy analytic hierarchy process (FAHP) technique to analyse, assess and improve the performance of SC operations. Based on the SCOR model, SC processes were mapped and their corresponding performance measures were identified. The relative weights (W) of SC performance measures were calculated using the FAHP technique, then a performance rate (R) was assigned for each measure with respect to a performance rating scale. Finally, the weighted rates (WR) of all measures were aggregated to calculate a supply chain index (SCI) which revealed the overall SC operations' performance.

To align SC operations' performance with a company's strategic financial objectives, a performance measurement method is developed linking SC performance metrics (SCOR FAHP technique) to a company's financial performance metrics. The Du Pont ratio was incorporated in the financial performance metrics. The analysis of this ratio illustrated the priorities of financial performance factors (revenue, cost and assets) through assessing the contribution of each factor to the improvement of the company's profitability and operating efficiency. The Dempster Shafer/Analytical Hierarchy Processes (DS/AHP) model was employed to determine the relative importance weights of the five main SC performance measures with respect to the priorities of financial performance factors.

The appropriate SC operational strategy was formulated with respect to the relative weights of SC performance measures and the priorities of financial performance factors. To evaluate the impact of SC operations' performance on enhancing the overall financial performance, a supply chain financial link index (SCFLI) was introduced and calculated before and after implementing the formulated SC operational strategy. A scenario approach was undertaken to illustrate how the developed method can be applied according to various possible financial results. A software application system was designed based on Structured Query Language (SQL) database to enable the real application of the developed research procedure. To demonstrate the applicability of the research procedure, a case study of a manufacturing company was conducted.

The research provides an original contribution to knowledge by creating a framework linking SC operations' performance to the company's strategic financial objectives for better alignment with the company's financial strategy. This research is also a contribution in that it proposes two indexes (SCI and SCFLI) to evaluate, monitor and control SC operations' performance. The analysis of these indexes provides continuous feedback on SC performance and allows tracing SC processes that need improvement resulting in more control over daily SC operations. Moreover, the developed research procedure helps companies to formulate the appropriate SC operational strategy by considering the targeted financial outcome and proposing the subsequent plans of action to enhance and control the performance of the relevant SC operations.

PUBLICATIONS ARISING FROM THIS WORK

- Elgazzar, S., Tipi, N.S. and Hubbard, N.J. (submitted January 2013), 'The impact of supply chain strategy on the financial performance' European Journal of Operational Research.
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- Elgazzar, S., Tipi, N.S., Hubbard, N.J. and Leach, D.Z. (2012) Linking SCM strategy to financial performance: a scenario analysis approach. *In: Proceedings of the 17th Annual Logistics Research Network Conference (LRN 2012)*, Cranfield, UK, 5-7 September 2012.
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- Elgazzar, S., Tipi, N.S., Hubbard, N.J. and Leach, D.Z. (2010) Incorporating fuzzy AHP in SCOR model for measuring supply chain operations performance: a case study of an Egyptian natural bottled water company. *In: Proceedings of the 15th Annual Logistics Research Network Conference (LRN 2010),* Harrogate, UK, 8-10 September 2010, pp.180-187.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process technique
AR	Action Research
BPA	Basic Probability Assignments
CAC	Codex Alimentarius Commission
CAGR	Compound Annual Growth Rate
CPA	Consumer Protection Agency
CR	Consistency Ratio
CI	Consistency Index
DBMS	Database Management System
DEA	Data Envelopment Analysis
DS/AHP	Dempster Shafer/Analytical Hierarchy Processes model
DST	Dempster-Shafer Theory
D.A.'s	Decision Alternatives
EVA	Economic Value Added
FAO	Food and Agricultural Organisation
FAHP	Fuzzy Analytic Hierarchy Process approach
FBMS	Function Based Measurement System
GSCF	Global Supply Chain Forum
G.MEAN	Geometric Mean
HACCP	Hazard Analysis for Critical Control Points
IBWA	International Bottled Water Association
KPIs	Key Performance Indicators
KRIs	Key Result Indicators
MBO	Management By Objective
MCDM	Multi Criteria Decision-Making process
NDA	Nondisclosure Agreement
OM	Operation Management
OR	Operation Research
OSCM	Operations and Supply Chain Management

PM^4TE	Performance Management For Turbulent Environment Model
PIs	Performance Indicators
ROA	Return On Assets
ROE	Return On Equity
SC	Supply Chain
SCC	Supply-Chain Council
SCFLI	Supply Chain Financial Link Index
SCPMS	Supply Chain Performance Measurement System
SCI	Supply Chain Index
SCM	Supply Chain Management
SCM KPIs	Supply Chain Management Key Performance Indicators
SCOR	Supply Chain Operations Reference-model
SMEs	Small and Medium-Sized Enterprises
SW	Software
SWOT	Strengths Weaknesses Opportunities and Threats
SQL	Structured Query Language database
WHO	World Health Organisation

CHAPTER ONE - INTRODUCTION

1.1 Introduction to the Research Topic

Due to the intense domestic and international competition that organisations currently face, companies will not be able to compete or survive unless they develop strategies to achieve cost reduction, quality improvement and increased productivity. However the real challenge for organisations is how to manage the trade-offs between such strategies as they usually work against one another. For example implementing strategy to achieve cost reduction could negatively impact quality or result in reduction in productivity. The management of material, products, information and time flow through the supply chain has a direct impact on the success of these strategies (Chan et al., 2002).

Traditionally, managers have considered that cutting stocks is all that is required for managing costs and hence improving performance (Christopher, 2005). Many organisations still rely on reviewing the financial aspects of their businesses to evaluate business performance. However, financial measures alone cannot provide a holistic view of the critical success factors (Umar and Olatunde, 2011).

Financial performance measures are governed by rules and guidelines which make them a simple and clear source of useful information about financial outcomes and the internal operations shown in the financial statements (Zuriekat et al., 2011). Although financial performance measures have been widely used to measure an organisation's performance, their ability to capture and reflect the different aspects related to an organisation's performance is limited. Financial performance measures are used to measure inputs and outputs through their codification into financial terms (Neely, 2003). These measures evaluate how well the organisation converts inputs into desired outputs without tracing the way in which the various inputs interact to produce the outputs. The inability to capture the organisation's processes that leads to such outputs makes these traditional financial measures unable to cope with the rapid changes in the business environment (Behn, 2003).

Since supply chain activities begin with a customer order and end when a satisfied customer has paid for his purchase, supply chain management has become a strategic tool to achieve the satisfaction of customer demand (Chopra and Meindl, 2007). A supply chain (SC) is a set of a company's entire operations directly and indirectly interlinked and interacted to transform inputs into outputs that are delivered to the end customer. Harrison and New (2002) reported the results of a major international survey undertaken in 1999 into the relationships between corporate strategy, supply chain strategy and supply chain performance management in manufacturing companies across the major industrialised countries. The survey revealed that 90 percentage of the respondents believed that supply chain performance was important or very important for achieving competitive advantage in the future (Forslund, 2007).

Managers at different levels should be aware of the connection between supply chain performance and the company's financial strategy, and how the company's daily actions can impact the overall financial performance. Presutti Jr. and Mawhinney (2007) stated that 70 percentage or more of manufacturing companies' expenditures are on supply chain-related activities, which highlights the potential impact of an effectively managed supply chain in contributing to overall improvement in financial performance.

Therefore, it is of value to develop a procedure aligning supply chain operational strategy and the company's overall financial strategy through linking SC operations' performance to the company's financial performance. After that, the impact of managing SC operations' performance on enhancing the financial performance of a company will be examined.

In addition, it will be beneficial to illustrate how this procedure can be applied in the manufacturing sector through conducting a case study within the context of the Egyptian market. In developing countries, there is still a significant lack of understanding of the concept of supply chain performance and the implementation of its practices (Saad and Patel, 2006). Although supply chain management has become essential for achieving business success, the term "supply chain" and the concepts of supply chain management are still not well known in the Egyptian market (Abdelsalam and Fahmy, 2009). Moreover, supply chain management is not yet in the forefront of determining a company's financial performance which highlights a need for an applied framework capturing the critical link between an organisation's SC operational strategy and its business performance. Understanding the link between SCM practices and financial performance improvement could help companies to gain competitive advantage through linking SC performance to the company's targeted financial objectives.

The remainder of this chapter is organised as follows. Section 1.2 defines the research aim and objectives. The research processes and the methodological tools employed in this research are illustrated in section 1.3. Section 1.4 identifies the research originality. Finally, section 1.5 outlines the dissertation structure and clarifies relationships between the research processes, the research methods and the structure of the dissertation.

1.2 Research aim and objectives

Based on the above discussion, the aim of this research is:

To develop a procedure to enhance the financial performance of manufacturing companies through managing performance of the supply chain operations.

Six objectives have been identified to achieve this aim:

1- To review the literature concerning supply chain performance and its link to overall financial performance.

2- To propose a technique to analyse, assess and improve the performance of supply chain operations.

3- To develop a performance measurement method to link supply chain operations' performance to the company's strategic financial objectives.

4- To design a software application system to measure and evaluate the impact of supply chain operations' performance on enhancing the company's overall financial performance.

5- To demonstrate the applicability of the proposed procedure through conducting a case study of a manufacturing company.

6- To propose a scenario analysis approach in order to illustrate how the developed research method can be applied according to various possible financial performance results.

1.3 Research methodology

The research applies a deductive research approach incorporating both quantitative and qualitative research methodologies. The stages and processes of the research methodology, by which the research aim and objectives will be achieved, are illustrated below:

1- Extensive review and analysis of published literature in the following research areas:

   - Performance measurement: to review the general issues of a performance measurement system and discuss the evolution of performance measurement from a traditional financial performance measurement system to the development of integrated performance measurement systems.

   - Supply chain performance management: to study different performance measurement systems and frameworks which propose to evaluate SC performance and provide an insight into the design and implementation of a performance measurement system in a SC context.

   - SC performance financial link: to discuss and analyse published literature that studies the links between supply chain management (SCM) practices and financial performance improvements.

2- Proposing a technique incorporating the fuzzy analytic hierarchy process approach (FAHP) and the Supply Chain Operations Reference-model (SCOR) to analyse, assess and improve the performance of SC operations.

3- Developing a performance measurement method to link SC operations' performance to a company's strategic financial objectives through demonstrating and utilising the relationship between SC operations' performance and the company's financial performance using the Dempster Shafer/Analytical Hierarchy Processes (DS/AHP) model.

4- Designing a software (SW) application system based on Structured Query Language (SQL) database utilising the proposed SCOR FAHP technique in order to enable the real application of the developed research methodology through measuring and evaluating the impact of supply chain operations' performance on the company's overall financial performance.

5- Conducting a case study of an Egyptian bottled water company in order to demonstrate the applicability of the research method and explore the impact of managing supply chain operations' performance using the proposed procedure on enhancing the company's financial performance.

6- Proposing a scenario analysis approach to illustrate how the developed research method can be applied in various possible financial performance contexts to determine the most appropriate supply chain operational strategy with regard to targeted financial objectives under possible scenarios.

The above stages of the research methodology are conducted based on data gathered, analysed and evaluated from primary and secondary sources. Primary data is collected from documentation, archival records, direct observations (formal, casual), a series of interviews (open ended interviews, focused interviews and formal survey) and informants. In addition to the primary data, secondary data is collected from books, online references and periodicals and specialised journals in logistics and supply chain management. Also, SCOR model (version 9) is employed at the stage of establishing the SCOR FAHP technique as a secondary source of data to map SC processes and identify the corresponding performance measures.

Figure 1.1 summarises the main phases of the research methodology.

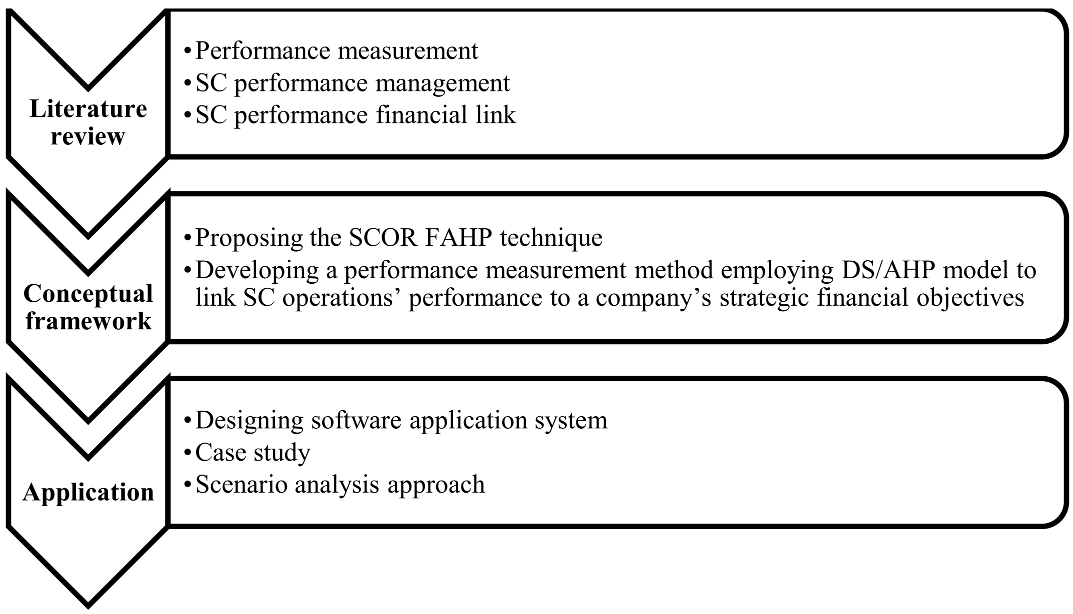


Figure 1.1: The main phases of the research methodology

1.4 <u>Research originality</u>

The following original contributions to knowledge are made through creating a framework aligning supply chain operational strategy and overall financial strategy for companies in the manufacturing sector.

1- Proposing a SCOR FAHP technique which provides an effective tool to manage and quantify SC operations' performance

The proposed technique introduces an effective tool to analyse, assess and improve the performance of supply chain operations through quantifying: SC measurement criteria, environmental uncertainty and the subjective judgements of SC performance evaluators. The developed SCOR FAHP technique is derived from Theeranuphattana and Tang (2008). Theeranuphattana and Tang (2008) proposed a model combining the SCOR model and the methodology developed by Chan and Qi (2003b) to identify and employ SC performance measures. Eliciting from this model, the proposed technique combines the FAHP method with the SCOR model to assess the performance of supply chain operations where the environmental uncertainty and subjective judgements of SC performance evaluators are determined and quantified using a fuzzy prioritisation method, adapted from Chang et al., (2009).

2- Developing a performance measurement method to link SC operations' performance to the company's strategic financial objectives using DS/AHP model.

A method derived from Presutti Jr. and Mawhinney (2007) is developed to link SC operations' performance to the company's financial performance. Presutti Jr. and Mawhinney (2007) focused on the performance of both processes and the output of processes. SC performance metrics measure the performance of SC processes in terms of reliability, responsiveness, agility, cost and asset management based on SCOR model standard performance metrics, while financial performance metrics evaluate and analyse the performance of the outputs of these processes based on the Economic Value Added (EVA) concept. The Presutti Jr. and Mawhinney (2007) method is developed further in this research by incorporating Du Pont ratio analysis in the financial performance metrics in order to analyse the financial performance in terms of efficiency and profitability. To link SC processes' performance to the company's financial performance, the developed method employs the DS/AHP model developed by Beynon et al. (2000). According to the DS/AHP model, the importance weight of the evaluation criteria is determined with respect to the priorities of related decision elements. Using this model, the importance weights of SC processes' performance measures can be determined with respect to the priorities of the company's financial strategy. Consequently, SC operational strategy is formulated based on these priorities through linking SC operational strategy to the focus area of enhancing financial performance.

3- The research introduces two indexes (Supply Chain Index (SCI) and Supply Chain Financial Link Index (SCFLI)) to evaluate SC operations' performance and link it to the company's financial performance.

   - Based on the SCOR FAHP technique, SCI with its operational levels is introduced to provide an overall view of SC performance. It can be analysed to assess the contribution of each SC performance measure to the overall SC performance. The analysis of this index mirrors the detailed performance of SC operations which allow companies to trace SC operations that need improvement and propose strategies to enhance their performance.

   - Based on the developed performance measurement method to link SC operations' performance to the company's strategic financial objectives, SCFLI with its strategic priorities is introduced to measure and evaluate the impact of supply chain operations' performance on enhancing the overall financial performance.

4- Designing a SW application system based on SQL database which enables the real application of the research method.

The developed SW application provides continuous feedback on supply chain performance and helps to decide the necessary corrective actions through calculating the two indexes (SCI and SCFLI). Analysing the indexes offers opportunities for detailed evaluation of SC operations' performance resulting in more control over the daily SC operations.

5- Scenario analysis approach is developed to illustrate how SC operational strategy can be linked to a company's financial performance in various possible financial performance scenarios.

This approach helps companies to formulate the appropriate SC operational strategy by considering the targeted financial outcome and proposing the subsequent plans of action to enhance and control the performance of the relevant SC operations.

1.5 Structure of the dissertation

This dissertation comprises the following chapters:

Chapter 1- Introduction: This chapter presents an overview of the research aim, objectives, methodology and originality. In addition, it outlines the dissertation structure and clarifies relationships between this structure and the research processes and methods.

Chapter 2- Literature review: This chapter critically reviews the literature in the areas of performance measurement systems, supply chain performance management and the link between SCM practices and financial performance improvements.

Chapter 3- Research methodology: Chapter three identifies the research scope, philosophy, approach and strategy, on which the theoretical framework is formulated and the methods, models and techniques used in creating it are discussed.

Chapter 4- Research framework: In this chapter, the scientific framework is formed and illustrated using a numerical example. The proposed SCOR FAHP technique and the performance measurement method to link SC operations' performance to a company's financial strategy are explained with a numerical example demonstrating them. The numerical example provides a holistic view of how the framework created can be implemented, making the implementation on the real case study- which presented in chapter five- much easier and more organised.

Chapter 5- Case study: development and findings: Chapter five presents the case study of the Egyptian bottled water company. Five major phases were carried out to conduct the case study namely; case design and preparation for data collection, introductory phase, establishing the SCOR FAHP technique, implementation phase and data analysis phase.

Chapter 6- Discussion: This chapter discusses significance of the case study findings in relation to study proposition and to previous research. In addition, the scenario analysis approach is introduced and explained based on five main alternative scenarios in order to illustrate how the research method can be applied in various possible financial performance results.

Chapter 7- Conclusion and recommendations for future work: Chapter seven presents the research conclusions, limitations and recommendations for further research.

Table 1.1 shows how the research processes relate to the research methods employed in this research and the structure of the dissertation.

Table 1.1: Research processes and the structure of the dissertation

No.	Research process	Research method	Chapter(s)
1	To review and analyse the published literature in the areas of performance measurement, SC performance management and the link between SCM practices and financial performance improvements.	Literature review	2
2	Identifying the research scope in order to select the appropriate research philosophy, approach and strategy. Then, formulating the theoretical framework and identifying the best suited methods, models and data collection techniques for this research.	Development of a theoretical framework	3
3	To propose a technique incorporating FAHP and SCOR model in order to analyse, assess and improve the performance of SC operations.	Development of a scientific	4

	To develop a performance measurement method to link SC operations' performance to the company's strategic financial objectives through demonstrating and utilising the relation between SC operations' performance and company's financial performance using DS/AHP model.	framework to be implemented	
4	To conduct a case study of an Egyptian bottled water company in order to demonstrate the applicability of the research method and explore the impact of managing supply chain operations' performance using the proposed procedure on enhancing the company's financial performance.	Case study research method	5
5	To design a software application system based on SQL database utilising the proposed SCOR FAHP technique in order to enable the practical application of the research method.	Software design and application methodology	5
6	To propose a scenario analysis approach in order to illustrate how the developed research method can be applied in various possible financial performance context and determine the most appropriate supply chain operational strategy with regard to the targeted financial objectives under possible scenarios.	Scenario analysis	6
7	To summarise, evaluate and interpret findings presented in chapter five through discussing the significance of key findings from the case study in relation to the research proposition and previous studies.	Analysis and interpretation of findings	6
8	**To evaluate the outcomes of the research processes 1 – 7, note limitations of the study and suggest practical applications and areas for future research**		7

In summary, this chapter introduced the research topic and based on this the research aim and objectives have been defined. It highlighted the research importance and clarified the original contributions to knowledge which would be reached on realisation of the aim and objectives. The chapter also presented the research methodology and processes by which the research aim and objectives will be achieved. Finally, the outline of the research structure and design was presented.

The next chapter will synthesise published literature in the related research areas in order to illustrate how this study would differ from, support, add to or even derive from previous studies. Based on a literature review, the research gap will be identified in a way that clarifies how this research will contribute to knowledge. Also, based on this review, the foundation of the research framework will be created and the best suited data collection techniques for this research will be selected.

CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

Interest in performance measurement and management has notably increased in the last 20 years. Companies have recognised that monitoring and understanding companies' performances have become essential to compete in continuously changing environments (Taticchi et al., 2010). Measuring an organisation's performance is necessary to evaluate its operations in order to identify bottlenecks and operations which create waste, determine necessary improvement and ensure that planned improvements actually happen (Parker, 2000).

Performance measurement can be defined as *"the process of quantifying the effectiveness and efficiency of action"* (Neely et al., 1995, p.80; Chan and Qi, 2003a, p.210). Effectiveness refers to the extent to which customer requirements are met, while efficiency measures how economically a company's resources are utilised when providing a pre-specified level of customer satisfaction (Neely et al., 1995; Shepherd and Gunter, 2006).

Moullin (2002, p. 188) defined performance measurement as an *"evaluation of how well organisations are managed and the value they deliver for customers and other stakeholders"*. This definition links performance measurement to organisational excellence through providing the performance measurement data needed to assess the extent to which an organisation achieves excellence and delivers value for customers and other stakeholders. In addition, this definition covers the four dimensions of the balanced scorecard. Financial aspects and the customer dimension are included in the delivery of value for customers and other stakeholders, while internal processes, innovation and learning are reflected by how organisations are managed (Moullin, 2007).

From the fifteenth century until the nineteenth century, organisational performance measurement was based on the results of the accounting system. Identifying profit and controlling cash flow were the main aspects to dominate organisational performance measurement (Morgan, 2004). In the early 1900s a turning point was achieved in organisational performance measurement when William Durant, founder of General Motors, realised that profit was not the result of accounting practices, but the outcome of a cost stream that spread throughout the supply chain (Drucker, 1995).

Mentzer et al. (2001, p.4) defined a supply chain as "a set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances and/or information from a source to customer".

Strategic supply chain management (SCM) improves the way processes are done and hence improves long-term performance (Harrison and Hoek, 2005). SCM has been documented to be positively associated with enhanced competitiveness and improved company performance (Li et al., 2006).

Traditional performance measurement systems, which rely on financial measures only, do not fit today's business environment (Umar and Olatunde, 2011). Linking SC performance to a company's financial performance can present an opportunity for companies to develop integrated performance measurement systems combining financial and non-financial measures by which companies can evaluate different aspects of organisational performance.

The remainder of this chapter is organised as follows. The next section reviews the literature in the field of performance measurement and discusses how performance measurement systems have evolved. Section 2.3 provides an extensive literature review of performance measurement particularly in a supply chain management context. Section 2.4 provides an insight on the design and implementation of a performance measurement system in a supply chain context. In this section, a conceptual model is developed and introduced to illustrate SCM integration within organisation and across the SC. Section 2.5 reviews published studies linking supply chain performance to a company's financial performance and section 2.6 concludes this chapter.

2.2 Performance measurement

According to Tangen (2003), performance measurement is an effective tool to develop competitive advantage and increase the productivity and the profitability of a company. There are several performance measures which organisations can use to assess their strengths and weaknesses. The challenge is to choose the most suitable single measure, or a combination of a set of measures. Appropriate performance measures can ensure that managers adopt a long-term perspective and allocate the company's resources to the most effective improvement activities. Many companies still rely on traditional, cost-related measures such as return on investment, profit margin and cash flow (Zuriekat et al., 2011). However, in today's business environment it is vital to combine performance measures to provide a balanced and fair assessment of the company (El-Baz, 2011; Agami et al., 2012; Bititci et al., 2012).

This section reviews the literature in the field of performance measurement. It starts with reviewing the literature highlighting the characteristics and the qualifications of an effective performance measurement system. Then, it discusses the main publications relating to performance measurement. Finally, it shows how performance measurement systems have evolved from the traditional financial performance measurement systems to integrated performance measurement systems incorporating financial and non-financial measures.

Neely et al. (1995) introduced several qualifications evaluating the goodness of a performance measure such as:

- Having a clear link between the performance measure and the organisation strategy.
- Being simple to understand.
- Being able to be controlled by either the person doing the measurement or their close associates.
- Being defined by the supplier and the consumer.
- Providing timely and accurate feedback about realistic targets.
- Being clearly defined and visible.
- Being a part of a feedback loop.
- Being presented in a clear and consistent format.
- Presenting data in terms of trends rather than absolutes and in terms of information rather than opinion or raw data.
- Being based on an agreed understanding of what is being measured and if possible using data that is automatically gathered as a part of the process.

Beamon (1996) identified the characteristics of an effective performance measurement system. These characteristics include: inclusiveness of all pertinent aspects, universality to allow comparison under various operating conditions, measurability of data required and consistency with organisation goals.

According to Tangen (2005) a performance measure should be relevant to the target business unit, clearly defined, easy to understand, combining financial and non-financial indicators and using a minimal number of metrics.

Tejas and Srikanth (2007) identified four characteristics to be considered when choosing a performance measurement metric. The metric should be reliable, valid, easily accessible and relevant to the processes or people concerned.

Bromberg (2009) discussed some of the challenges hindering the development of a performance measurement system for the purposes of improving performance and accountability. The findings revealed that developing a successful performance measurement system requires its purposes to be clearly set and its targeted outcome clearly identified.

According to Vitale et al. (1994), although an efficient and effective performance measurement system should incorporate financial and non-financial measures, it should not try to measure everything. Managers should be able to determine where value is being created and where investment and improvement are required. The research proposed a six-step methodology describing how to design and implement an efficient and effective performance measurement system starting with specifying the goal, then matching measures to strategy, identifying the measures, predicting the results, building commitment and finally planning the next step.

Neely et al. (2005) reviewed performance measurement system design. The review focused on three pivots to analyse a performance measurement system. The first pivot was the performance measures. Regarding this pivot, the study revealed that the most important measures of manufacturing's performance are related to quality, time, cost and flexibility. The second pivot was to deal with the performance measurement system as an entity. In this pivot, the study reviewed the various dimensions of a performance measurement system and categorised the “balanced scorecard” as the best known performance measurement framework. The balanced scorecard is based on the principle that a performance measurement system should provide managers with sufficient information to address the financial perspective, internal business perspective, customer perspective and the innovation and learning perspective. The third pivot was related to the environment of a performance measurement system. With respect to this pivot, the study classified the performance measurement system environment into two dimensions, the internal environment which presents the organisation itself and the external environment to reflect the market within which the organisation competes.

Bull (2007) categorised an organisation’s performance measurement into three “effs” dimensional views (efficiency, effectiveness and efficacy) in order to distinguish between three different strategies: a resource-based strategy, a market-led strategy and a success-led strategy. A resource-based strategy focuses on measuring costs through assessing how efficiently a process’ inputs are utilised to produce a targeted output. A market-led strategy assesses how effectively a company can respond to demand and add value. It focuses on measuring the value of output generated from given inputs. A success-led strategy focuses on measuring success through assessing to what extent the inputs produced the required output. It determines the efficacy level at which a company achieves its vision and intended results.

Parmenter (2007) distinguished between three types of performance measures: key result indicators (KRIs), the performance indicators (PIs) and the key performance indicators (KPIs). KRIs reflect an organisation’s performance and determine whether the performance results are in the right direction towards planned goals through indicating how an organisation has performed in terms of critical success factors or with respect to the balanced scorecard perspectives. Although KRIs provide a clear picture of the achievement of the planned goals, they do not guide the organisation on what to do to achieve these goals. Both, the PIs and the KPIs identify what should be done to enhance the current performance. However, the KPIs focus on the performance aspects that are the most important to dramatically increase performance. This is why Parmenter recommended that an organisation may have up to 80 PIs but they should have no more than ten KPIs.

Cagnazzo et al. (2010) classified performance measurement models into six groups:

- Balanced models integrating financial and non-financial indicators.
- Quality models in which a great importance is attributed to quality.
- Questionnaire-based models.
- Hierarchical models where there is a clear hierarchy of indicators.
- Support models that help in the identification of the factors that influence performance indicators.
- Supply chain oriented models to evaluate a SC context.

Willis and Anderson (2010) argued that determining the exact type and combination of quantitative and qualitative performance measurement data is subject to the purpose of the assessment and the availability of data. Also, the context within which the performance measurement system is developed should be considered which requires the contribution of all staff within an organisation from the strategic level to the operational levels in order to connect organisational resources and operations to short, medium and long term strategic objectives.

Although intangible capital represents 80% of the value of the average organisation, most of the current performance measurement systems were built without considering it. Designing a performance measurement system addressing the intangible capital requires the following steps:

prior to designing the system, the company needs to take an inventory of its competencies, relationships, brands, processes and intellectual property to show how the intangible capital can be utilised to create value for customers. Then investments in intangible capital are calculated to generate a report of intangible inventories' accounts on a quarterly or annual basis for assessment purposes. Based on this assessment, the priorities of intangibles can be determined to fit the company's strategic priorities. Finally, the performance measurement system can be designed providing performance results of the tangible assets as well as the intangible assets (Adams, 2011(adapted from Adams and Oleksak, 2011)).

Neely and Barrows (2011) developed a new model for the measurement of performance management in turbulent environment s (PM^4TE). The PM^4TE model has been engineered to be used specifically with the challenges of turbulent environments where simplicity, speed and adaptability are required. Since, the speed of learning is central to success in a turbulent environment, the PM^4TE model enables organisations to deal with performance measurement not as a controlling process but as a learning process. It focuses on improving the practices of management itself rather than improving the frameworks and the enabling technologies through distinguishing between three distinct cycles: the performance management cycle, the execution management cycle and model enablers.

The model is based on four steps: causal performance modelling, setting up projects, measuring progress and making decisions. First, a causal business model is built and tested through identifying performance criteria and success factors and measuring the relationships between them. Based on the first step, organisations can set up projects that impact success factors. The model explicitly links projects to performance through conducting specific projects to deliver high performance. Then performance is measured with key performance indicators to determine whether performance criteria and success factors are improved or whether there is a need to rebuild the causal business model. Finally, based on information created in the previous steps, decisions can be taken and their impact on achieving performance targets evaluated.

Striteska and Spickova (2012) conducted a review to analyse, compare and summarise the strong and weak points of the most widely cited performance measurement systems. The review identified seven performance measurement systems as the most widely adopted performance measurement systems: the Balanced Scorecard, the European Foundation for Quality Management (EFQM) Excellence Model, the Performance Measurement Matrix, the SMART Performance Pyramid, the Performance Prism (PP), Kanji Business Excellence Measurement System (KBEMS) and Theory of Constraints (TOC).

The literature showed that the Balanced Scorecard and the SMART Performance Pyramid are two excellent performance measurement systems at the company's strategic level to clarify goals, define performance objectives and communicate selected strategies. The Performance Measurement Matrix integrates different dimensions of business performance (financial and non-financial as well as internal and external). The main focus of the Performance Prism, KBEMS and TOC is to respond to changing priorities, while the EFQM model is more suitable for benchmarking. The study also highlighted that although these conceptual frameworks have a clear theoretical background, they did not provide guidance on how a company should design its specific performance measurement system.

The review revealed that further practical research is required to explore how the above mentioned systems can be translated and tailored to fulfil the company's specific measurement needs, particularly at the operational level.

Bititci et al. (2012) conducted a review synthesis to investigate the readiness of contemporary performance-measurement literature and practice for the currently emerging context and predicted future trends, particularly cultural and multicultural aspects of performance measurement, collaborative organisations, autopoietic networks, servitization, sustainability and the open source movement.

The review indicated that the real challenge within the emerging context is to develop an integrated and holistic understanding of performance measurement through: understanding performance measurement as a social system, understanding performance measurement as a learning system and understanding performance measurement in autopoietic networks. Accordingly, the review proposed a holistic systems-based framework identifying the gaps in knowledge and presenting practical and theoretical challenges for performance measurement in response to emerging business and global trends.

Another review conducted by Searcy (2012) of key literature published between 2000 and 2010 on corporate sustainability performance measurement systems (SPMS). The review highlighted a need for additional research to enhance both the practical and theoretical aspects of corporate SPMSs. It revealed that further research on the implementation and use of corporate SPMSs is required, particularly empirical research to investigate the factors affecting the success and failure of SPMS implementation. The review concluded by identifying future directions for research in the design, implementation, use and evolution of corporate SPMS.

Korhonen et al. (2013) elaborated on the notion of performance measurement (PM) dynamism. The paper identified the rationale and the levels of PM dynamism and discussed its relationship to the formal and informal domains of management control. Literature review and an interventionist case study were conducted to provide a thorough understanding of how and at what levels managers need dynamism in performance measurement systems.

The review revealed the dynamic role of performance measurement at four different levels: decision making, use of measures, selection of measures and within the components of single measures. A theoretical framework was created based on literature review to illustrate the rationale and the elements of PM dynamism. To demonstrate how PM dynamism takes place in practice, a case study of a private healthcare organisation was conducted. Finally, the empirical findings from case study were aligned with the created theoretical framework, up on which managerial practice of PM dynamism was suggested to help managers identify dynamism needs in their performance measurement systems.

Grosswiele et al. (2013) proposed a decision framework for performance measurement systems (PMS) consolidation considering the informational and economic challenges of information provision. The proposed framework was constructed to enable the comparison of different consolidated PMS based on performance measurement system-related requirements extracted from the management accounting, operations management, and performance measurement literature. A method for guiding the process of PMS consolidation was developed by which information processing complexity and costs can be balanced to meet decision makers' information requirements and to align with corporate objectives.

Feature comparison, prototype construction, and a real-world application were conducted to evaluate the proposed decision framework. Since the decision framework has not yet been adopted by the industry, feature comparison was used to discursively evaluate the characteristics of the framework through comparing it with a checklist of requirements that should be met by an appropriate decision framework for PMS consolidation. Prototype construction proved that many parts of the developed PMS consolidation process can be automated which enable reducing manual effort. The real-world application complemented the other two evaluation steps (i.e. feature comparison and prototype construction) through empirically demonstrating the usefulness of the proposed decision framework for experts involved in PMS consolidation.

Table 2.1 summarises the main publications reviewed in this section concerning performance measurement.

Table 2.1: The main publications on performance measurement

No.	Author	Year	Contribution/Approach
1	Neely et al.	2005	Identified three pivots to analyse a performance measurement system: the performance measures, the performance measurement framework and the environment of a performance measurement system.
2	Bull	2007	Categorised an organisation's performance measurement into three "effs" dimensional views (efficiency, effectiveness and efficacy) in order to distinguish between three different strategies: a resource-based strategy, a market-led strategy and a success-led strategy.
3	Parmenter	2007	Distinguished between three types of performance measures: key result indicators (KRIs), the performance indicators (PIs) and the key performance indicators (KPIs).
4	Cagnazzo et al.	2010	Classified performance measurement models into six groups: balanced models integrating financial and non-financial indicators, quality models, questionnaire-based models, hierarchical models, support models that help in the identification of the factors that influence performance indicators and supply chain oriented models.
5	Willis and Anderson	2010	Identified three elements to determine the exact type and combination of quantitative and qualitative performance measurement data: the purpose of the assessment, the availability of data and the context within which the performance measurement system is developed.
6	Adams	2011	Designed a performance measurement system addressing the intangible capital through conducting four steps. First, an inventory of the company's intangible assets is created. Then investments in intangible capital are calculated to generate a report of intangible inventories' accounts on a quarterly or annual basis for assessment purposes. Based on this assessment, the priorities of intangibles can be determined to fit the company's strategic priorities. Finally, the performance measurement system can be designed providing performance results of the tangible assets as well as the intangible assets.
7	Neely and Barrows	2011	Developed the PM^4TE model for the measurement of performance management in turbulent environments (PM^4TE). The model focuses on improving the practices of management through distinguishing between three distinct cycles: the performance management cycle, the execution management cycle and model enablers.
8	Striteska and Spickova	2012	Conducted a review to analyse, compare and summarise the strong and weak points of the most widely cited performance measurement systems. The review identified seven performance measurement systems as the most widely adopted performance measurement systems: the Balanced Scorecard, the

			European Foundation for Quality Management (EFQM) Excellence Model, the Performance Measurement Matrix, the SMART Performance Pyramid, the Performance Prism (PP), Kanji Business Excellence Measurement System (KBEMS) and Theory of Constraints (TOC).
9	Bititci et al.	2012	Conducted a review synthesis to investigate the readiness of contemporary performance-measurement literature and practice for the currently emerging context and predicted future trends. The review proposed a holistic systems-based framework identifying the gaps in knowledge and presenting practical and theoretical challenges for performance measurement in response to emerging business and global trends.
10	Searcy	2012	Conducted a review of key literature published between 2000 and 2010 on corporate sustainability performance measurement systems (SPMS), upon which future directions for research in the design, implementation, use and evolution of corporate SPMS were identified.
11	Korhonen et al.	2013	Elaborated on the notion of performance measurement (PM) dynamism by identifying the rationale and the levels of PM dynamism and discussing its relationship to the formal and informal domains of management control. Literature review and an interventionist case study were conducted to provide a thorough understanding of how and at what levels managers need dynamism in performance measurement systems.
12	Grosswiele et al.	2013	Proposed a decision framework for PMS consolidation considering the informational and economic challenges of information provision. The proposed framework enabled the comparison of different consolidated PMS and demonstrated the process by which information processing complexity and costs can be balanced to meet decision makers' information requirements and to align with corporate objectives.

According to Gomes et al. (2004), performance measurement evolved through two phases. The first phase began in the late 1880s and was characterised by a cost accounting orientation and incorporated financial measures, such as profit and return on investment. However, these traditional measures failed to measure and integrate all the factors critical to business success. The second phase was started in the late 1980s and it was associated with the growth of global business activities and the changes resulting from such growth. In this phase, the emphasis has been directed to the development of integrated performance measurement systems incorporating financial and non-financial measures.

Financial performance measures evaluate the results of an organisation’s policies and operations in monetary terms in order to indicate the extent to which financial objectives have been accomplished over a given period of time. From a financial perspective, measuring financial performance relies on financial measures such as operating income, return on investment and residual income. These measures are usually obtained from the financial accounting system and provide information in terms of monetary units or ratios of monetary units (Eldenburg and Wolcott, 2005).

Financial results are reported in the form of financial statements which provide relevant financial data for internal and external users through summarising two important financial aspects related to the business: profitability and financial position. The two basic statements are the Balance Sheet and the Income Statement. The Balance Sheet shows a company's financial position at a specific date through reporting its assets, liabilities and owner's equity. The Income Statement reflects the profitability of the company over a specific period of time through presenting the revenues, expenses and resulting net income or net loss (Weygandt et al., 2010). However, financial statements do not reveal all the information related to the financial performance of an organisation. To get a full and detailed picture of the profitability and financial position of the business, financial statements should be analysed and interpreted through the use of one or more techniques of financial analysis.

One of the most important and widely used techniques is the ratio analysis. A financial ratio expresses the numerical relationship between two or more figures derived from the financial statements or other sources of financial information (Salmi and Martikainen, 1994). Financial ratios are classified into five main groups: profit ratios, liquidity ratios, activity ratios, leverage ratios and shareholder-return ratios in order to reveal the financial strengths and weaknesses of a company in different financial dimensions. The analysis of financial ratios allows the evaluation of the financial performance of a company compared with the industry average or the company's prior years of performance (Hill and Jones, 2011).

However, relying on traditional financial methods and techniques alone to measure a company's performance is no longer the norm in large organisations (Basu, 2001). Financial performance measures are important at the strategic level; while measuring the performance of day to day operations can be handled better with non-financial measures (Maskell, 1991; Iveta, 2012). Although most companies realise the importance of combining financial and non-financial performance measures, they have failed to represent them in a balanced framework (Gunasekaran et al., 2004). A balanced performance measurement framework should reflect a company's strategic and financial objectives along with the financial impact of supply chain performance on an overall company's performance. Supply chain processes and roles need to be mapped onto a combination of financial and non-financial metrics aligned to the overall business strategy and addressing the performance of various supply chain functional areas (Tejas and Srikanth, 2007).

2.3 Measuring SC performance

SC performance measurement provides the tools to monitor SC operations' performance and to reveal the effectiveness of a company's strategies. In addition, it can provide feedback to enable managers to diagnose problems and identify success and potential opportunities (Ramaa et al., 2009). Many researchers have proposed differing performance measures and metrics to measure supply chain performance (Neely, 2005; Shepherd and Gunter, 2006; Gunasekaran and Kobu, 2007). This section reviews the published research on SC performance measurement systems where a critical analysis will be provided. The research studies included in the review are categorised into six main groups according to their common focus:

- Functional based SC measurement system

- Process based SC measurement system
- Integrated SC performance measurement system
- SC performance modelling
- Prioritisation and choice of SC metrics and measures
- Critical review on SC performance measurement

Section 2.3.1 discusses the shift from functional based SC measurement systems to process based SC measurement systems in the late 1990s. Section 2.3.2 shows that by the beginning of the 21st century, integrated SC performance measurement systems were developed, with the integrated SC performance modelling approach being identified as one of the main approaches to measure integrated SC performance. Section 2.3.3 illustrates various approaches dealing with the prioritisation and choice of SC metrics and measures. Finally, the main critical reviews that have been conducted on SC performance measurement are discussed in section 2.3.4.

2.3.1 Shift towards process focused SC performance measurement systems

Prior to the late 1990s, SC performance measurement systems were functionally focused. Christopher (1992) developed a function-based measurement system (FBMS) combining different performance measures to cover different processes in the supply chain. Although this performance measurement system is easy to implement and can be applied to individual departments, it does not involve top level measures to cover the entire supply chain. The lack of these strategic measures hinders the ability to look at the supply chain with respect to a company's strategy.

In the late 1990s, the focus in the area of measuring SC performance started to shift from the functional-focused measurement systems to process-focused measurement systems. Several authors suggested implementing business processes in the context of supply chain management (Cooper et al., 1997; Srivastava et al., 1999; Bowersox et al., 1999; Mentzer, 2001; Morgan, 2007; Naslund and Williamson, 2010; Agami et al., 2012)

Lambert et al. (2005) identified five supply chain management frameworks that recognise the need to implement standardised business processes across corporate functions and across companies.

The first framework is the SCOR model. The SCOR model was developed in 1996 by the Supply-Chain Council (SCC) and has been used by many researchers (Bullingery et al., 2002; Huang et al., 2004; Hwang et al., 2008; Theeranuphattana and Tang, 2008; Camerinelli, 2009; Kremers, 2010; Bai et al., 2012; Agami et al., 2012; Kocaoˇglu et al., 2013). This model is based on five core processes (plan, source, make, deliver and return) and divided into three levels of process detail (top level, configuration level and process element level) (Supply-Chain Council, 2008). The model attempts to integrate the concepts of business process reengineering, benchmarking, process measurement and best practice analysis which allows the upper management of a company to make connections between strategies and measurements and to concentrate on key processes and measures that have a significant impact on the overall performance of a SC (Lockamy and McCormack, 2004; Huang et al., 2005).

It includes standard performance metrics to measure the performance of SC processes as well as a set of benchmarking tools for performance and process evaluation which allow companies to compare and benchmark their processes against those of other companies (Huan et al., 2004).

The second framework was developed in 1996 by the Global Supply Chain Forum (GSCF) (Lambert and Cooper, 2000). It consists of three primary related elements: the supply chain network structure, the supply chain business processes and the management components (Cooper et al., 1997). The supply chain network structure consists of the members of the SC, from the raw materials to the ultimate customer and the links between these members. The supply chain business processes are the activities that produce valuable output to the customer. Eight supply chain management processes are included in the GSCF framework: customer relationship management, customer service management, demand management, order fulfilment, manufacturing flow management, supplier relationship management, product development and commercialisation and returns management. The management components determine how the business processes are managed and structured. The GSCF framework includes the following management components that support the processes: planning and control, work structure, organisation structure, product flow facility structure, information flow, management methods, power and leadership structure, risk and reward structure and culture and attitude (Lambert et al., 1998).

The third framework developed by Srivastava et al. (1999) includes three business processes: customer relationship management, product development management and supply chain management. The fourth framework was a SCM framework introduced by Bowersox et al. (1999) and focused on three "contexts": operational, planning and control and behavioural. This framework was further developed by Melnyk et al. (2000) to include eight business processes: plan, acquire, make, deliver, product design/redesign, capacity management, process design/redesign and measurement. Mentzer et al. (2001) developed the fifth framework which focused on the cross-functional interaction within a company and on the relationships developed with other supply chain members.

These five frameworks represent different process-based SC measurement systems. However, only the GSCF and SCOR frameworks were described in the literature in sufficient detail to allow meaningful comparisons to be made between the two frameworks (Lambert et al., 2005).

Lambert et al., (2005) used four criteria to compare these two frameworks in order to provide an insight into the approaches to supply chain management that each one takes. These criteria are: scope in terms of the ties to corporate strategy and the breadth of the activities, the degree of intra-company and inter-company connectedness and the drivers of value generation.

This comparison indicated that the GSCF Supply Chain Management Framework has a wide scope as it touches all aspects of the business. It focuses on aligning each of the eight supply chain management processes with organisational and functional strategies through customer and supplier relationship management which makes the framework relationship-oriented. In the GSCF framework, operational measures are tied to the drivers of the company's economic value added (EVA). This is due to the breadth of its framework and its focus on the corporate strategy as the main strategic driver.

On the other hand, SCOR processes are developed based on the operations strategy. Positioning the SCOR processes within operations strategy and prioritising implementation initiatives that result from the framework will help maximise impact through aligning resources and goals with operations strategy. The model framework has a limited scope as it focuses only on engaging partners from the logistics, production and purchasing functions of the supply chain in its five supply chain management processes. The SCOR model focuses on identifying areas of improvement in order to provide cost reductions and improve asset efficiency which makes its framework operational efficiency-oriented rather than relationship-oriented.

The following table summarises the main differences between the SCOR model and the GSCF model. However, it should be noted that these two models are not mutually exclusive or can be used only as two alternative approaches. Section 2.4.2 will discuss in more detail how these two frameworks can be integrated and applied on different levels of SCM; whether within an organisational structure or across the SC.

Table 2.2: The main differences between The SCOR Model and The GSCF model

	SCOR model	**GSCF model**
Focus	Transactional efficiency	Relationship management
Processes driver	Processes are developed from operations strategy	Processes are aligned with organisational and functional strategies through customer and supplier relationship management
Scope	Limited scope An analysis using this framework would focus only on engaging partners from the logistics, production and purchasing functions of the supply chain	Wide scope The GSCF framework touches all aspects of the business
Drivers of Value Generation	Cost reduction and asset utilisation	Economic Value Added

(Adapted from: Lambert et al., 2005)

2.3.2 <u>Shift towards integrated SC performance modelling approaches</u>

By the beginning of the 21st century, significant attention was directed to the development of integrated SC performance measurement systems within an organisation and across the SC. Researchers started to focus on designing systems combining financial and non-financial measures and incorporating different levels of decision making (strategic, tactical and operational) in order to set performance targets to reflect company strategy and objectives. SC performance modelling has been one of the main approaches used to measure integrated SC performance. Several SC performance models have been developed to evaluate integrated SC performance and analyse the reasons underlying performance and the relationship between performance factors.

Beamon (1999) introduced an integrated framework to measure supply chain performance. The research identified three types of performance measures as necessary components in any SC performance measurement system: resources, output and flexibility. Although many researchers before Beamon discussed the importance of resources and output measures for measuring supply chain performance, flexibility was limited in its application to SCs. She highlighted the importance of flexibility, in terms of how well the system reacts to uncertainty, as a vital component to SC success.

Sabri and Beamon (2000) proposed an integrated multi-objective supply chain model to integrate strategic and operational analysis of the supply chain. The model provides a comprehensive performance measurement system including cost, customer service levels and flexibility in order to evaluate the efficiency and effectiveness within the supply chain.

Gunasekaran et al. (2001) classified SCM systems based on their strategic, operational or tactical focus. The operational level is concerned with the daily operation of a facility, the tactical level focuses on the location of decision spots and the objectives of the chain while the strategic measures require an understanding of the dynamics of a supply chain and development of objectives for the whole chain.

Frohlich and Westbrook (2001) empirically analysed manufacturers' SC integration strategies and tested the relationship between SC integration and performance. Five different SC strategies were identified through characterising the direction (towards customers and/or towards suppliers) and degree of SC integration as key dimensions for representing strategic position. The research used evidence from an international manufacturing strategy survey collected from 322 companies in 23 countries about the practice and performance related to manufacturing strategy.

The study specified eight different types of activities by which manufacturers can integrate their operations with suppliers and customers. Then, scales were developed for measuring SC activities integration by classifying manufacturer into either the upper, middle, or lower quartiles with supplier and/or customer integration. Accordingly, five different SCM integration strategies were identified. The results revealed that the widest degree of integration with both suppliers and customers had the strongest association with performance improvement.

Bullingery et al. (2002) suggested a measurement methodology integrating bottom-up and top-down performance measures based on SCOR model and balanced scorecards as a hybrid balanced measurement approach. The method incorporated SCOR metrics into the supply network scorecards to form an integrated measurement system. The SCOR metrics provided a bottom-up metric focusing on controlling material and product flows to measure logistics performance. The adoption of balanced scorecards to supply network scorecards provided a top-down controlling approach measuring management performance in order to keep the supply chain on track towards realising business strategy and achieving improvement goals. Together, the two metrics constitute a holistic instrument for the measurement of logistics process performance.

Lai et al. (2002) developed a measurement model and a measurement instrument for supply chain performance in transport logistics based on SCOR model and various established measures. They introduced a 26-item SC performance measurement instrument reflecting service effectiveness for shippers, operations efficiency for transport logistics service providers and service effectiveness for consignees.

Otto and Kotzab (2003) presented a framework to measure the effectiveness of SCM. They introduced six unique sets of metrics differing between six perspectives on SCM: system dynamics, operations research, logistics, marketing, organisation and strategy. Each perspective follows a particular set of goals, which consequently leads to a particular set of performance metrics.

Chan and Qi (2003b) developed a process-based model to analyse and manage the supply chain and measure its performance. In this model, the SC is represented by six core business processes: supplying, inbound logistics, manufacturing, outbound logistics, marketing and sales and end-customer processes.

Liang et al. (2006) designed data envelopment analysis (DEA) -based models for characterising multi-member supply chain operations and calculating the efficiencies of the supply chain and its members. These models represent a managerial tool enabling the direct evaluation of multi-member supply chain operations. To illustrate the applicability of the developed models, a seller-buyer supply chain was used as an example. The relationship between the buyer and the seller was modelled first in a leader-follower structure and second in a cooperative structure. Non-linear programming problems were developed to solve these supply chain efficiency models.

Chen et al. (2006) investigated the efficiency between two supply chain members. They developed two efficiency functions for the supplier and the manufacturer. The results illustrated the existence of numerous equilibrium efficiency plans for both supplier and the manufacturer regarding their efficiency functions. Based on these results, a bargaining model was proposed to analyse the supplier and manufacturer's decision process and to determine the most efficient plan.

Wong and Wong (2007) used DEA as a modelling tool to construct two models of efficiency (the technical efficiency model and the cost efficiency model) for measuring internal supply chain performance efficiency.

Theeranuphattana and Tang (2008) proposed a model combining the SCOR model and process-based model developed by Chan and Qi (2003b) in order to identify and employ SC performance measures. According to this model, the relative importance of SC performance measures are calculated from the fuzzy pair-wise comparisons with respect to the changing SC objectives and strategies, then the performance grades are assigned for these measures. After the performance grade sets and the relative weights of all the performance measures are determined, the measurement results of all attributes can be aggregated through the weighted average aggregation method in order to reveal the overall SC performance.

Charan et al. (2008) employed an interpretive structural modelling-based approach to determine the key supply chain performance measurement system (SCPMS) implementation variables on which senior management should focus in order to improve the effectiveness and efficiency of the supply chain. The model analysed the interaction among the SCPMS implementation variables through developing a single systemic framework to link the various variables of a SCPMS. According to this model, the SCPMS implementation variables have been categorised into "enablers" and "results". The enablers are the variables that help the SCPMS implementation, while the results variables are the outcome of the SCPMS implementation.

Cai et al. (2009) proposed a framework to solve the iterative key performance indicators (KPIs) accomplishment problems in a supply chain context. The proposed framework quantitatively analyses the interdependent relationships among a set of KPIs through calculating the estimated cost, impact, and risk associated with each alternative set of KPIs. Since it provides a holistic view of complex relationships among KPIs, this framework can serve as a useful modelling tool for speeding up performance improvements in dynamic supply chain decision-making environments and refining the process of selection amongst a large number of KPIs.

Aramyan et al. (2009) developed a performance measurement model which evaluated the impact of quality assurance systems on the performance of the supply chain. The model applied an adapted self-explicated method categorising SC performance measures in four groups: efficiency, flexibility, responsiveness and quality.

Tipi (2009) emphasised the modelling aspects of SC performance measurement systems in the simulation context. A simulation model was constructed using discrete event simulation to address some of the challenges of designing and modelling performance measures for complex supply chain systems. The model analysis focused on evaluating the way in which performance measures can be built when simulation is used.

Azevedo et al. (2011) proposed a conceptual model analysing the influence of a set of lean, agile, resilient and green SCM practices named "LARG practices" on SC performance. This model offers a checklist to identify possible practices to achieve the strategic goals. It gives insights on how to make SC's leaner, agile, more resilient and greener to achieve the operational, economic and environmental SC performance objectives.

Kotzab et al. (2011) developed a conceptual model identifying antecedents that affect the adoption and execution of SCM in terms of internal and external integration of business processes to create value and to improve total performance of the chain. The model identified three antecedents that affect the level of execution of SCM: internal SCM conditions which are required for adopting and implementing SCM-related processes within the organisation, joint or external SCM conditions which are required for adopting and implementing SCM-related processes across the SC, and SCM-related processes which indicate business activities that integrate or coordinate different key business areas within a company and with its partners across the SC.

Hypothesised hierarchical order of the three identified antecedents was proposed and verified empirically through conducting a survey of 174 senior supply chain managers representing the biggest organisations within a central European country. The results revealed that internal and external SCM conditions are antecedents of the adoption of SCM-related processes, which in turn affect the level of execution of SCM. The study provided a set of measurement scales that operationalised constructs within this model and helped companies to focus on those SCM conditions and processes that need to be prioritised in order to increase SCM adoption and execution. By adapting the proposed hierarchical order of these three antecedents, companies can accomplish the full execution of SCM.

Gimenez et al. (2012) conducted a survey to investigate the effectiveness of supply chain integration in different contexts. Data were collected among manufacturers in The Netherlands and Spain to measure different dimensions or aspects of supply chain integration and supply complexity. The results showed that supply chain integration increases performance in high supply complexity environments, while supply chain integration has a very limited or no influence on performance in low supply complexity environments. The study concluded that high levels of supply chain integration are only required in high supply complexity environments. Since implementing supply chain integration is difficult and costly, companies should focus on integrating with customers with a high supply complexity.

Deshpande (2012) designed an integrated theoretical framework based on a comprehensive literature review. The developed framework utilised the interrelationships between SCM dimensions, SCM performance and organisation performance for effective implementation of SCM. The framework identified three major dimensions to measure SCM performance: SC delivery flexibility, inventory cost and customer responsiveness time. The study revealed the importance of interactions between elements of supply chain management in order to enhance the organisation's ability to meet desired goals. Findings indicated improvements in SCM performance in terms of delivery flexibility, inventory cost reduction and customer responsiveness time as a result of managing long-term relationships and implementing concurrent engineering.

Agami et al. (2012) proposed a hybrid dynamic framework for SC performance improvement integrating various sciences, methodologies, and tools. Systems thinking, strategic planning, optimisation, balanced scorecards, SCOR model and theory of constraints thinking were integrated to develop a process-based approach for measuring, managing and improving SC performance. The proposed framework contributed to the enhancement of currently existing SCPM systems by adding two additional steps to the traditional SCPM process, namely: optimisation and TOCTP implementation. Optimisation was adopted - as an intermediate stage between performance evaluation and performance management- to identify critical KPIs that need improvement. Finally, TOCTP tools were employed to suggest the appropriate improvement strategies for those previously identified critical KPIs.

Bai et al. (2012) introduced a grey based neighbourhood rough set methodology to evaluate, select and monitor sustainable supply chain performance measurement that can be integrated into a performance management system. The applicability of the methodology was illustrated in a case example based on the SCOR model through introducing existing and new performance measures that cover both traditional business and environmental measurements associated with the SCOR "sourcing" function. Companies using this methodology can clearly identify and narrow the key environmental and business performance measures for sustainable supply chains.

Kocaoˇglu et al. (2013) proposed the ‘TOPSIS–AHP–SCOR integrated approach’ for linking strategic objectives to operations. Based on SCOR model, strategic attributes and performance metrics suitable for the needs were determined. Techniques for order preference by similarity to ideal solution (TOPSIS) and AHP were combined to develop a collaborative decision and evaluation processes. First, TOPSIS was used to normalize performance metrics’ values that have different units. Then, the AHP was used to analyze these metrics hierarchy and determine the relative importance of competitive priorities of attributes and performance metrics. Consequently, the weighted normalized evaluation matrix was constructed and finally, TOPSIS procedures were conducted to evaluate and achieve the final ranking of the different scenarios’ supply chain performance. The research applied the proposed integrated approach to a problem of decision making process in a manufacturing company in order to demonstrate its applicability.

This section reviewed previous studies focused on development of integrated supply chain performance measurement systems. Different approaches and models were proposed to address SCM integration from different perspectives such as:

- incorporating different types of measures (financial and non-financial measures, quantitative and qualitative measures or operational, economic and environmental measures)
- covering different business aspects (different processes, different functions or different dimensions)
- incorporating different levels of decision making (operational, tactical and strategic)
- considering multi-objectives (sustainability, quality assurance, profitability, efficiency, managing cash flow or improving communication channels)
- addressing different directions (towards customers and/or towards suppliers)

- covering different domains (within the organisation and across the SC)

The review revealed that these perspectives are not mutually exclusive. An integrated SC performance measurement system may address more than one of these perspectives. The higher the level of SCM integration a system can consider, the more successful SCM this system can accomplish.

Aggregated performance measurement systems aim to present the “bigger picture” - i.e. the overall performance- which can be easier to interpret and communicate among different players within the supply chain (Tipi et al. 2008). SCM integration helps eliminate many non-value-adding activities from internal and external production processes, which consequently reduces variability and in turn leads to greater efficiency along with faster delivery of finished goods (Frohlich and Westbrook, 2001). Kotzab et al. (2011) identified four levels of SCM integration:

- Internal level which refers to the integration of SC activities within the focal company.
- Dyadic level which refers to a single two-party relationship between the focal company and one member of the chain.
- Chain level which includes a set of dyadic relationships.
- Network level which presents a wider level of operational integration within the SC network structure.

However, the level, type, direction and degree of integration are subject to the purpose of the assessment and the context within which the SC performance measurement system is developed. The effectiveness of supply chain integration in terms of performance improvement is influenced by SC context. Since SC integration is not a one-dimensional concept, the distinct effect of different dimensions (practices, patterns and attitudes) on different supply chain performance measures should be considered (Gimenez et al., 2012).

2.3.3 <u>Prioritisation and choice of SC metrics and measures</u>

Another main aspect to SC performance research has been the prioritisation and choice of SC metrics and measures. Various approaches have been proposed to deal with the hierarchical nature of SC performance measures and to handle the complexities of the multi- criteria decision making problems inherent in SC performance measurement related decisions.

Chan (2003) utilised the analytic hierarchy process (AHP) technique to make decisions based on the priority of SC performance measures. AHP is a technique used for solving multi-criteria decision making problems involving tangible and intangible, quantitative and qualitative aspects. Using this technique, the complex problem is broken down into sub-problems in a hierarchy of different levels of elements. Then, priorities among the elements are determined and finally, the priorities of these elements are combined to establish the final decision. In order to use AHP as a tool to measure SC performance, all relevant performance measures are firstly defined and then quantified. Then, a pair-wise comparison matrix is used to determine priorities among the elements of performance measures. Finally, the weights of each element in each hierarchical level are aggregated to the next level, noting that weighting can be altered according to the characteristics of different industries.

Hwang et al. (2008) proposed a stepwise regression method to prioritise different SC performance measures. A case study was conducted based on the SCOR model. The study specifically focused on the SCOR sourcing processes to identify the important SCOR sourcing performance metrics using the developed stepwise regression method.

Askariazad and Wanous (2009) introduced a new holistic approach for identifying and prioritising supply chain performance measures according to their importance in the evaluation of value-added activities in the entire supply chain. A pair-wise questionnaire based on the AHP methodology was designed to prioritise the main supply chain functions, processes and criteria. The approach developed helps managers and practitioners to identify the most important, practical and strategic performance measures in their supply chains.

Najmia and Makuia (2010) combined the AHP and DEMATEL to rank SC performance measures and identify the most important factors affecting the performance of the supply chain. DEMATEL is one of the most popular multi-criteria decision making approaches based on the concept of pair-wise comparison of decision characteristics. According to this methodology, the appropriate metrics are selected with respect to organisation strategy and then compared with an ideal supply chain of the same class. The DEMATEL is used for understanding the relationship between comparison metrics and AHP is used for the integration to provide a value for the overall performance.

El-Baz (2011) proposed a fuzzy decision making system based on fuzzy set theory and the AHP technique to deal with SC performance measurement systems in the manufacturing environment. Compared to currently existing systems which measure general dimensions such as flexibility, cost, quality and innovation for the company, the proposed system enabled identifying measures for each department in order to diagnose the strengths and weaknesses of the performance indicator. A numerical example of a manufacturing company was conducted to aggregate the effects of different quantitative and qualitative factors on performance into a single indicator. First, various factors affecting performance were identified. Then, the relative importance weights of these factors were evaluated using the AHP technique. Finally, data were collected from the company's departments in order to determine the performance indicator for each department using the proposed fuzzy decision making system.

Vaidya and Hudnurkar (2013) proposed a multiple criteria approach to evaluate SC performance. The proposed approach started with assigning importance weights to SC performance links with respect to the organisational goals using pair comparison method. For each link in the SC, the various criteria for performance evaluation were identified, then an importance weight was assigned to each criterion in each SC link. The performance value of each criterion was evaluated in accordance to set benchmark. Consequently, the performance contribution for each criterion in each link was calculated as the product of the weight and performance value of the criterion. Then, links performance values were evaluated as the summation of performance contributions of all criteria for each link. Finally, the performance contributions for links were calculated as the product of the weights and performance values of the links, up on which the performance parameter for the entire supply chain was computed as the summation of links performance contributions.

The proposed approach can be flexibly modified to suit different supply chain structures and to apply to any number of criteria. Adopting this approach enables linking performance criteria with the organisational goals and provides a holistic view of analysing SC performance. A case study of a manufacturing company was presented to demonstrate the practical benefits of the proposed approach.

Perera et al. (2013) developed a model to quantify the environmental performance of a manufacturing company's SC based on the analytical hierarchy process (AHP) technique as a multi-criteria decision making approach. The AHP was used along with Expert Choice software to select and quantify the environmental performance measures. The model was applied to a case study company to identify the key areas of environmental performance of the company's supply chain and to assess various product categories manufactured under those key areas.

This section illustrated various methods and approaches proposed to identify and prioritise SC performance measures. The reviewed studies showed that most of researchers have employed multi-criteria decision making approaches -particularly AHP approach- to deal with the prioritisation and choice of SC metrics and measures. The review revealed that the process of prioritisation and choice of SC metrics and measures enables companies to align their SC performance measurement systems with the organisational goals through identifying the relevant SC performance measures and assigning their relative importance weights with respect to the strategic objectives.

On the other hand, companies need to determine the influence weight of each SC performance measure on the overall SC performance. Although the aggregation of SC performance measures provides a holistic view of analysing SC performance, companies should be able to drill down to different measures and different levels of detail in order to trace the contribution of each SC performance measure to the overall performance, and consequently recommend improvement strategies for those critical measures that need improvement.

2.3.4 Critical reviews on SC performance measurements

Shepherd and Gunter (2006) critically reviewed articles published between 1990 and 2005 on performance measurement systems and metrics used in supply chains. This review provided a taxonomy of SC performance measures and a critical evaluation of measurement systems designed to evaluate the performance of supply chains. The paper classified the studies as operational, design or strategy focused studies. Operational studies develop mathematical models for improving the performance of the supply chain, design studies focus on redesigning the supply chain to optimise performance, while strategy studies aim to align the supply chain with a company's strategic objectives.

Gunasekaran and Kobu (2007) analysed articles published between 1995 and 2004 on performance measures and metrics in SC systems. This review revealed the use of over eighty performance measures. After an alphabetical listing of all these measures, the authors concluded that some measures were exactly the same where others were practically the same but with different titles. They removed all the repeating and over-lapping measures leaving 27 measures representing SCM key performance indicators (KPIs).

They also categorised performance measurement in logistics and SC into seven main categories:

The first category was the balanced score card which includes four perspectives: financial perspective, internal process perspective, innovation and improvement perspective and customer perspective. The second category focused on components of performance measures such as time, resource utilization, output and flexibility measures. In the third category, the performance measures were classified according to their location in the supply chain links (Planning and Product Design, Supplier, Production, Delivery and Customer). Performance measures in the fourth category were classified based on Decision-making levels (Strategic, Tactical and Operational). In the fifth category measures were classified according to their nature i.e. financial or non-financial. The sixth category classified performance measures as quantitative measures or non-quantitative measures. In the final category, a function-based measure was classified as a traditional measure while a value-based measure was classified as a modern measure.

Another review conducted by Tipi et al. (2008) to evaluate how supply chain performance measures are currently selected, modelled and analysed for different supply chains and to assess the appropriateness of the existing measures for analysing a supply chain system.

The study revealed that modelling aspects of supply chain performance measures need to receive more attention from academics and practitioners. The currently developed modelling approaches for design and analysis of supply chain system are still very limited and only scratched the surface. For better judgment on the selection of performance measurement system, the review recommended future research in supply chain modelling demonstrating the interrelationships between performance measures and how these interrelationships can be affected by changes in supply chain strategies or decision variables.

Akyuz and Erkan (2010) conducted a critical review on supply chain performance measurement. The review revealed that the area of supply chain performance measurement research is still in need of further investigation regarding framework development. Previous research in this area has often failed to develop a fully integrated supply chain performance measurement framework. In addition, the study highlighted the importance of the balanced scorecard approach and the SCOR model as the foundation of research in the SC performance measurement field. The review declared that today's SC competitive environment requires a SC performance measurement framework which can: truly capture the essence of organisational performance; be based on company strategy and objectives; allow for setting targets; reflect a balance between financial and non-financial measures; relate to the different levels of decision making and control; be determined through discussion with all the parties involved; enable fast feedback and continuous improvement; adopt a proactive approach; clearly define the purpose and related methodology; be valid and reliable; be comparable to other performance measures used by similar organisations; enable aggregation and prioritisation; facilitate integration; be simple and easy to use; avoid overlaps; and be in the form of ratios rather than absolute numbers.

Gopal and Thakkar (2012) conducted a comprehensive review of articles published between 2000 and 2011 on supply chain performance measures and metrics. The review studied 28 key articles reported in the domain of supply chain performance measurement through classifying them on the basis of three phases of the performance measurement system process: designing of measures, implementing of measures and monitoring of measures.

Designing of measures phase referred to design supply chain performance measures for improving overall supply chain performance. Studies in this phase focused on classification of measures and development of SC performance measurement frameworks and conceptual models. Implementing of measures phase considered studies which focused on empirical testing of frameworks through conducting surveys and case studies to understand the implementation issues associated to supply chain performance measures. While monitoring of measures phase included studies that introduced practical guidelines and benchmarking issues for monitoring of supply chain performance in order to reveal the gap between planning and execution and help companies to identify potential problems and areas for improvement.

The review highlighted a need for longitudinal case study approach to understand the factors affecting supply chain measures and to understand the supply chain performance measurement models behaviours' in both developing and developed countries. It revealed that the process of development of metrics and measures should consider different structures of the supply chain through understanding the level of synchronisation of supply chain activity with the level of complexity in management of measures for each supply chain structure. The review also indicated that there is a large scope for further research in the domain of supply chain measures and metrics, specifically the issues related to characteristics of measures and metrics, benchmarking of measures, use of management practices, integration and partnership and socio-environmental relevance.

Hassini et al. (2012) reviewed literature published during last decade (2000-2010) on sustainable supply chains. The review focused on the tactical and the operational aspects of sustainable supply chains in decision sciences publications. It has been found that the majority of the reviewed papers used analytical models such as AHP, Fuzzy decision making, simulation and decision support methods. The second most used method has been found to be the case study. Although case study methodology is still not well utilised in operations management research, sustainability as a relatively new research area, has focused on the case study methodology to help understanding the real issues and problems.

The paper analysed sustainable supply chains literature from different perspectives: industry sectors, firm sizes, supply chain drivers and supply chain partner. Since sustainable practices may differ from one industry to another, the review classified literature based on industry sectors. It has been found that the majority of the reviewed literature focused on manufacturing sectors. This was explained by two factors. Traditionally, operations research has focused on production and manufacturing topics and historically environmental regulations have focused on manufacturing plants. For the same reasons, the classification of the reviewed literature according to which partner of the supply chain was the focus of study has showed that the majority of papers focused on the manufacturer.

The review revealed that large firms have an advantage for adopting sustainable practices more than small and medium-sized enterprises (SMEs). Thus, more research on the adoption of sustainable practices in SMEs is required. The review also classified literature based on six major drivers for supply chain performance: transportation, inventory, facilities, information, pricing and sourcing. Most reviewed studies focused on transportation and information drivers, only one paper addressed the pricing driver, while no studies focused on the inventory driver.

Based on this review, the paper extracted two frameworks: one for managing sustainable supply chains and the other for the development of performance measures for sustainable supply chains. A framework for sustainable supply chain management was proposed based on six pivots representing the major relevant functions within the chain: sourcing, transformation, delivery, value proposition, customers and recycling. The framework identified the major external and internal factors that may push a supply chain to adopt sustainable operations. Consequently, the major obstacles in developing sustainable supply chain metrics were identified and a framework was developed based on composite indicators in order to create reliable performance measures for sustainable supply chains. A case study of an electric utility company was provided to illustrate the experience of a utility supply chain in setting sustainable SC performance indicators. The case showed a need for such composite indicators for maintaining sustainable supply chain practices and highlighted that more complex reliable performance indicators are required.

As shown in the previous discussion, various performance measurement systems have been proposed to evaluate SC performance but they have also been criticised in the academic literature. Amongst the most widely highlighted criticisms of current performance measurement systems in supply chain management (SCM) are (Chan, 2003; Chan and Qi, 2003a; Gunasekaran et al., 2004; Gunasekaran and Kobu; 2007; Ramaa et al., 2009; Akyuz and Erkan, 2010; Agami et al., 2012):

- The lack of a connection with strategy.
- The failure to integrate financial and non-financial measures.

- Too many metrics, and an incompleteness and inconsistency in performance measurement.
- The lack of systems thinking.

Pervious research did not provide a comprehensive methodology for analysing supply chains and understanding the relationship between SCM performance measures and organisational performance measures, particularly the complexities of SCM and organisation performance in a unified context. Researchers have not yet captured the linkages between different dimensions of SCM and the impact of these dimensions on SCM performance (Deshpande, 2012).

In addition, capturing the link between strategic objectives and operations is still immature in the literature and a little far from being effectively applied in terms of how to model and how to analyse. The literature revealed that current performance measurement systems in supply chain management cannot address the conflict between the top down strategy decomposition and the bottom-up implementation process (Kocao˘glu et al., 2013). Today's SC competitive environment requires process based SCPMS defined at both executive and operational levels, aligned to overall business objectives, covering the performance of all supply chain processes in a company and can be used across the SC (Gintic Institute of Manufacturing Technology, 2002). The current evolution of organisations needs a shift towards process focused measurement systems (Morgan, 2007). Standardisation of business processes has become essential to link those processes within the members of the supply chain and to conduct a meaningful comparison of organisational performance (Naslund and Williamson, 2010). Table 2.3 summarises the focus and contributions of the works reviewed in this section.

Table 2.3: Classification of the research studies on SC performance measurement with respect to focus and contribution

No.	Author	Year	Focus	Contribution/Approach
1	Christopher	1992	Functional based SC measurement system	Developed a function based measurement system (FBMS) combining different performance measures to cover the different processes in the supply chain.
2	Supply-Chain Council (SCC)	1996	Process based SC measurement system	Developed the SCOR model based on five core processes (plan, source, make, deliver and return). The model includes standard performance metrics to measure the performance of SC processes as well as a set of benchmarking tools for performance and process evaluation.
3	the Global Supply Chain Forum (GSCF)	1996	Process based SC measurement system	Developed the GSCF model which consists of three primary related elements: the SC network structure, the SC business processes and the management components.
4	Beamon	1999	Integrated SC performance measurement system	Introduced an integrated framework to measure the supply chain performance based on classifying the performance measures in three categories (resource, output and flexibility).
5	Srivastava et al.	1999	Process based SC measurement system	Introduced a process focused SC measurement framework includes three business processes: customer relationship management, product development management and supply chain management.
6	Bowersox et al.	1999	Process based SC measurement system	Introduced a process focused SC measurement framework focuses on three "contexts": operational, planning and control and behavioural.
7	Sabri and Beamon	2000	SC performance modelling	Proposed an integrated multi-objective supply chain model to integrate strategic and operational analysis of supply chain.
8	Melnyk et al.	2000	Process based SC measurement system	Developed the SC measurement framework introduced by Bowersox et al. (1999) to include eight business processes: plan, acquire, make, deliver, product design/redesign, capacity management, process design/redesign and measurement.
9	Gunasekaran et al.	2001	Integrated SC performance measurement system	Classified SCM systems based on their strategic, operational or tactical focus.
10	Mentzer et al.	2001	Process based SC measurement system	Introduced a process focused SC measurement framework focused on the cross-functional interaction within a company and on the relationships developed with other SC members.
11	Frohlich and Westbrook	2001	Integrated SC performance measurement system	Identified five different integration strategies that manufacturers could undertake in relation to suppliers and customers based on characterising the direction (towards customers and/or towards suppliers) and degree of SC integration as key dimensions for representing strategic position.
12	Bullingery et al.	2002	Integrated SC performance measurement system	Suggested a hybrid balanced measurement approach integrating bottom-up and top-down performance measures based on SCOR model and balanced scorecards.
13	Lai et al.	2002	SC performance modelling	Developed a measurement model and a measurement instrument for SC performance in transport logistics based on the SCOR model and various established measures.
14	Chan	2003	Prioritisation and choice of SC metrics and measures	Used the AHP technique as a tool for measuring SC performance.
15	Chan and Qi	2003b	SC performance modelling	Developed a process-based model represented by six core business processes to analyse, manage the supply chain and measure its performance.

16	Otto and Kotzab	2003	Integrated SC performance measurement system	Presented a framework to measure the effectiveness of SCM based on six unique sets of metrics differing between six perspectives on SCM.
17	Liang et al.	2006	SC performance modelling	Designed DEA-based models for characterising multi-member supply chain operations and calculating the efficiencies of the supply chain and its members.
18	Chen et al.	2006	SC performance modelling	Proposed a bargaining model to analyse the supplier and manufacturer's decision process and determine the best efficiency plan strategy.
19	Shepherd and Gunter	2006	Critical review on SC performance measurement	Critically reviewed articles published between 1990 and 2005 on performance measurement systems and metrics of supply chains and classified the reviewed studies as operational, design or strategic.
20	Gunasekaran and Kobu	2007	Critical review on SC performance measurement	Conducted a review to analyse the published articles between 1995–2004 on performance measures and metrics in SC systems and categorised the performance measurement in logistics and SC systems in seven main categories. The review introduced 27 KPIs after all repeats and over lapped measures are taken out.
21	Wong and Wong	2007	SC performance modelling	Constructed a modelling tool based on DEA to measure the internal SC performance efficiency.
22	Theeranuphattan a and Tang	2008	SC performance modelling	Proposed a model combining the SCOR model and process-based model developed by Chan and Qi (2003b) in order to identify and employ SC performance measures.
23	Charan et al.	2008	SC performance modelling	Employed an interpretive structural modelling based approach to determine the interaction among the SCPMS implementation variables.
24	Hwang et al.	2008	Prioritisation and choice of SC metrics and measures	Proposed a stepwise regression method to prioritise different SC performance measures.
25	Tipi et al.	2008	Critical review on SC performance measurement	Evaluated how supply chain performance measures are currently selected, modelled and analysed for different supply chains and assessed the appropriateness of the existing measures for analysing a supply chain system.
26	Askariazad and Wanous	2009	Prioritisation and choice of SC metrics and measures	Introduced a holistic approach based on the AHP methodology to identify and prioritise SC performance measures according to their importance in the evaluation of value-added activities in the entire supply chain.
27	Cai et al.	2009	SC performance modelling	Developed a modelling tool for speeding up performance improvements in dynamic supply chain decision-making environments and refining the process of deciding among large number of KPIs.
28	Aramyan et al.	2009	SC performance modelling	Developed performance measurement model evaluating the impact of quality assurance systems on the performance of the supply chain.
29	Tipi	2009	SC performance modelling	Constructed a simulation model to address some of the challenges of designing and modelling performance measures for complex supply chain systems.
30	Najmia and Makuia	2010	Prioritisation and choice of SC metrics and measures	Combined the AHP and DEMATEL to rank SC performance measures and identify the most important factors affecting the performance of the supply chain.

31	Akyuz and Erkan	2010	Critical review on SC performance measurement	Conducted a critical review on SC performance measurement. The review revealed that SC performance measurement research area is still in a need of further research regarding development of fully integrated SC performance measurement frameworks. In addition the study highlighted the importance of the balanced scorecard approach and the SCOR model as the foundation of the research in SC performance measurement area.
32	Azevedo et al.	2011	SC performance modelling	Proposed a conceptual model analysing the influence of a set of lean, agile, resilient and green SCM practices on SC performance.
33	Kotzab et al.	2011	SC performance modelling	Developed a conceptual model identifying three antecedents (Internal SCM conditions, external SCM conditions and SCM-related processes) which affect the adoption and execution of SCM in terms of internal and external integration of business processes to create value and to improve the total performance of the chain.
34	El-Baz	2011	Prioritisation and choice of SC metrics and measures	Proposed a fuzzy decision making system based on fuzzy set theory and the AHP technique to deal with SC performance measurement systems in the manufacturing environment through aggregating the effects of different quantitative and qualitative factors on performance into a single indicator.
35	Gimenez et al.	2012	Integrated SC performance measurement system	Conducted a survey to investigate the effectiveness of supply chain integration in different contexts.
36	Deshpande	2012	Integrated SC performance measurement system	Designed an integrated theoretical framework utilising the interrelationships between SCM dimensions, SCM performance and organisation performance for effective implementation of SCM.
37	Agami et al.	2012	Integrated SC performance measurement system	Proposed an integrated hybrid dynamic process-based framework for SC performance improvement incorporating various sciences, methodologies and tools. The proposed framework contributed in the enhancement of currently existing SCPM systems by adding two additional steps to the traditional SCPM process, namely: optimisation and TOCTP implementation.
38	Bai et al.	2012	SC performance modelling	Introduced a grey based neighbourhood rough set methodology to evaluate, select and monitor sustainable SC performance measurement that can be integrated into a performance management system.
39	Gopal and Thakkar	2012	Critical review on SC performance measurement	Conducted a comprehensive review of articles published between 2000 and 2011 on supply chain performance measures and metrics. The review studied 28 key articles reported in the domain of supply chain performance measurement through classifying them on the basis of three phases of the performance measurement system process: designing of measures, implementing of measures and monitoring of measures.
40	Hassini et al.	2012	Critical review on SC performance measurement	Reviewed literature published during last decade (2000-2010) on sustainable supply chains and analysed it from different perspectives. The review proposed frameworks for sustainable supply chain management and performance measures, then provided a case study of sustainable supply chain performance indicators in the energy sector.
41	Kocao˘glu et al.	2013	Integrated SC performance measurement system	Proposed ‘TOPSIS–AHP–SCOR integrated approach’ which links strategies to operations using AHP and TOPSIS techniques based on SCOR model. The proposed approach was applied to a problem of decision making process in a manufacturing company.

42	Vaidya and Hudnurkar	2013	Prioritisation and choice of SC metrics and measures	Proposed a multiple criteria approach to evaluate SC performance using pair comparison method. The proposed approach was flexibly designed to suit different supply chain structures and to apply to any number of criteria. A case study of a manufacturing company was presented to demonstrate the practical benefits of proposed approach.
43	Perera et al.	2013	Prioritisation and choice of SC metrics and measures	Developed and solved a model to select and quantify the environmental performance measures of a manufacturing company's SC based on the AHP technique and Expert Choice software.

2.4 Designing and implementing a performance measurement system in a SC context

Developing a performance measurement system is critical to achieve successful implementation of SCM practices (Cagnazzo et al., 2010). Effective SCM requires a performance measurement system that can appropriately reflect actual SC performance (Azevedo et al., 2011). Beamon (1999) and Gunasekaran et al. (2001) indicated that several studies have provided insights on the design and implementation of performance measures in a SC context; however the process of choosing an appropriate SC performance measurement system is complex. According to Tangen (2005), there is no single optimal measurement tool that can be applied to SC performance as different performance measures can be selected for different purposes. Firstly, the fundamental purpose of performance measurement should be defined, then the appropriate measure can be chosen according to the intended purpose. This section provides an insight on the design and implementation of a SC performance measurement system. Firstly, it focuses on understanding and analysing the characteristics, the structure and the strategy of the targeted supply chain as a primary step to develop an effective SC performance measurement system. Secondly, it discusses the guidelines for the selection of an appropriate supply chain framework in order to identify, map and evaluate SC processes. Finally, it gives insights on modelling supply chain benchmarking in order to establish the appropriate performance metrics and identify the integration among them.

2.4.1 Analysing the characteristics, the structure and the strategy of a supply chain

Different supply chains have different length, type, focus, strategy and as a result different goals to be accomplished. Some organisations may control supply chains through to the end customer, others might only operate until downstream distribution points. Some supply chains may share logistic providers or storage locations, while others might be dedicated to a particular product (UNICEF, 2009). Therefore, understanding and analysing the characteristics, the structure and the strategy of the targeted supply chain is an essential primary step to develop an effective SC performance measurement system for improved SCM.

SC network structure is embedded within social, political and economic context. Internal and external factors such as socio-economic and institutional context have been found to influence network and supply chain structure and process (O'Reilly et al., 2003). Findings from several studies proved that the influence of SC integration on performance is moderated by SC context (Germain et al., 2008; Gimenez et al., 2012). Organisational cultural fit between supply chain partners should be investigated as one of the factors that impact SC performance. Achieving successful performance outcomes requires attention to cultural evaluation as well as finance or strategic evaluations (Cadden et al., 2013). As stated earlier, analysing the characteristics, trends and relationships within an organisation's internal and external environment is considered one of the most important aspects to develop an appropriate SC performance measurement system (Neely et al., 2005; Willis and Anderson, 2010).

The external environment analysis provides a basic description of the industry through identifying key external stakeholders, analysing industry trends and examining the competitive forces that dominate it with an emphasis on growth and profit potential, upon which keys to survival and success in the industry can be drawn. The internal environment analysis is required to evaluate the organisation’s strategic direction, resources, capabilities and internal and external relationships. Accordingly, the organisation’s strengths and weaknesses can be identified with respect to external environment analysis - which has been previously done- so that the full range of opportunities and threats can also be identified (Harrison and John, 2009).

After analysing the external and internal environment, the next step should be analysing the structure of the targeted SC. Stock et al. (2000) proposed a framework of fit between logistics integration and supply chain structural elements. The framework introduced two constructs defining supply chain structure. The first construct is the geographic dispersion which refers to the geographic scope of the suppliers' locations, production facilities, distributors and customers in the supply chain. The extent to which the supply chain is either concentrated or dispersed geographically has a significant impact on the decision-making authority and coordination within the company. The second construct is channel governance which illustrates the classification of how the company's suppliers, production facilities, distributors and customers are governed. Three different configurations of channel governance are considered according to this framework: networks, hierarchies and markets.

Beamon and Chen (2001) classified supply chain structures into four main structure types: convergent, divergent, conjoined, or general (network). Convergent structures are assembly-type structures in which each node in the chain has at most one successor, but may have any number of predecessors. Divergent structures are types of structures where each node has at most one predecessor, but any number of successors. A conjoined structure is one that combines convergent and divergent structure, where each comprising substructure (convergent and divergent) is combined in sequence to form a single, connected structure. General (network) structure is the one that does not fall into any of the preceding three structures where the general structure is neither strictly convergent, divergent nor conjoined.

The GSCF model demonstrated the SC network structure including all members with whom the focal company interacts directly or indirectly from the point of origin to the point of consumption. These members are divided into primary members and supporting members. The primary members are those who carry out value-adding activities in the business processes designed to produce a specific output for a particular customer or market, while supporting members are companies that provide resources, knowledge, utilities, or assets for the primary members of the supply chain. By determining primary and supporting members, the point of origin and the point of consumption of the supply chain can be identified. The point of origin of the supply chain occurs where no previous primary suppliers exist while the point of consumption is where no further value is added and the product and/or service is consumed (Spens and Bask, 2002).

In addition, the GSCF framework identified three structural dimensions of the network to be determined when describing, analysing and managing the supply chain. These dimensions are the horizontal structure, the vertical structure and the horizontal position of the focal company within the supply chain. The horizontal structure dimension refers to the number of tiers across the supply chain. The vertical structure dimension refers to the number of suppliers/customers represented within each tier. The company's horizontal position within the supply chain describes the company location in the supply chain between the point of origin and the point of consumption (Brewer et al., 2001).

Another important aspect that should be taken into consideration when analysing a supply chain is to clearly identify supply chain strategy. Christopher and Towill (2001) argued that customer satisfaction and market place understanding are the main aspects when establishing supply chain strategy. Lean and agile represent the two main types of supply chain strategies; however they are not mutually exclusive paradigms and may be combined in a number of different ways where hybrid strategies can be developed (Mason- Jones et al., 2000; Chan and Kumar, 2006).

A lean strategy focuses on the elimination of waste with a bias towards "pulling" goods through the system based on demand. Lean is a make-to-stock system, reacting to "demand signals" which come from forecasts or next tier distributors, rather than actual orders. On the other hand, the agile system focus is on flexible, efficient response to unique customer demand. The agile system uses a make-to-order process for manufacturing and order fulfilment. Agility employs a "wait-and-see" approach to demand, not committing to products until demand becomes known (Goldsby et al., 2006). Table 2.4 illustrates the comparison of attributes, characteristics and key differences in logistics strategy between lean and agile supply.

Table 2.4: Comparison of Lean supply chain with Agile supply chain

	Lean supply chain	**Agile supply chain**
Distinguishing attributes		
-typical products	Commodities	Fashion goods
-marketplace demand	Predictable	Volatile
-product Varity	Low	High
-product life cycle	Long	Short
-customer drivers	Cost	Availability
-profit margin	Low	High
-dominant costs	Physical costs	Marketability cost
-stock out penalties	Long term contractual	Immediate and volatile
-purchasing policy	Buy materials	Assign capacity
-information enrichment	Highly desirable	Obligatory
-forecasting mechanism	algorithmic	Consultative
Characteristics		
-logistics focus	Eliminate waste	Customers and markets
-partnerships	Long term, stable	Fluid clusters
-key measures	Output measures such as productivity and cost	Measure capabilities and focus on customer satisfaction
-process focus	Work standardisation, conformance to standards	Focus on operator self-management to maximise autonomy
-logistics planning	Stable, fixed periods	Instantaneous response
Key difference in logistics strategy	Concerned with placing orders upstream for products that move in regular flow	Concerning with assigning capacity so that products can be made rapidly to meet demand that is difficult to forecast

(Source: Harrison and Hoek, 2008)

After analysing the targeted supply chain, the next step to develop an effective SC performance measurement system is to select an appropriate SC performance framework. Different supply chains characteristics and strategies require different frameworks. Selecting the appropriate supply chain framework in order to identify, map and evaluate the processes in the entire supply chain is essential for providing a structure to assess the whole supply chain system.

2.4.2 Selecting the appropriate supply chain framework

UNICEF (2009) defined a supply chain framework as *"a management tool to help identify and map the activities associated with all phases of a supply chain"*. To develop an effective SC performance measurement system, the selected framework should be reliable, provide a scope of measurement and reveal the viability of strategies (Gunasekaran et al., 2001).

Different types of supply chain systems require different performance measurement characteristics. Various SC performance measurement frameworks for different types of systems have been developed in order to facilitate the analysis and the evaluation of supply chain performance (Beamon, 1999). The two most broadly applicable frameworks are the Global Supply Chain Framework (GSCF) and The Supply Chain Operations Reference (SCOR) Model (Johnson and Mena, 2008). These two frameworks represent two different approaches to implementing standard cross-functional integrated business processes in the context of SCM.

However, these two models can be integrated and linked to achieve SCM on the organisational level and throughout SC network structure. As illustrated in section 2.3.1, the SCOR model is linked to operational strategy. The narrow focus of the SCOR on achieving transactional efficiency through engaging partners from the logistics, production and purchasing functions makes it an appropriate framework to achieve cross functional business processes integration within the organisation's structure.

Cirtita and Glaser-Segura (2012) conducted a survey in US industry to investigate the extent to which the SCOR model is used to coordinate intra-organisational activities and downstream supply chain (DSC) inter-organisational activities. The results revealed that the surveyed companies accepted the SCOR model as a standardised comprehensive performance system for measuring intra-organisational performance. However, it was found that companies are used the SCOR metrics independently of DSC inter-organisational coordination activities. It has been explained that companies might aim to first coordinate the internal performance metrics, and then later will extend external metrics with DSC members.

On the other hand, the wide scope of the GSCF framework - which provides key business processes aligned with organisational and functional strategies through customer and supplier relationship management- makes it more adapted for achieving SCM integration among the members within SC network structure.

Companies' internal activities in some way are linked with other members of the SC. The structural of activities within and between companies is considered one of the critical elements that impact SC performance. Linking and managing internal key activities and business processes across SC members can increase profitability and competiveness within organisations and across SC network, which requires changing from managing individual functions to integrating activities into cross functional key SC business processes. The main challenge is that companies in the same SC may have different processes' names, numbers, links and levels which can impact the communication between SC members and consequently, the efficiency of SCM integration. Function approach by nature has a relatively unified understanding since the main functions like marketing, manufacturing and finance already have general description and implications. Moreover, companies in the same SC network may have different strategic objectives resulting in different performance priorities and different critical processes to manage and to integrate within the organisation and with other members of the SC (Lambert and Cooper, 2000). A prerequisite of successful SCM integration across SC network is to accomplish cross functional business processes integration within the company (Lambert and Cooper, 2000; Kocao˘glu et al., 2013).

The SCOR model provides standard description of SC processes and the relationship among these processes by which members in the SC can have a unified description and understanding of their SC processes. In addition, the SCOR model standard performance metrics can provide standardised key performance indicators to evaluate the performance of the entire SC, the individual members of the chain or subsets of members.

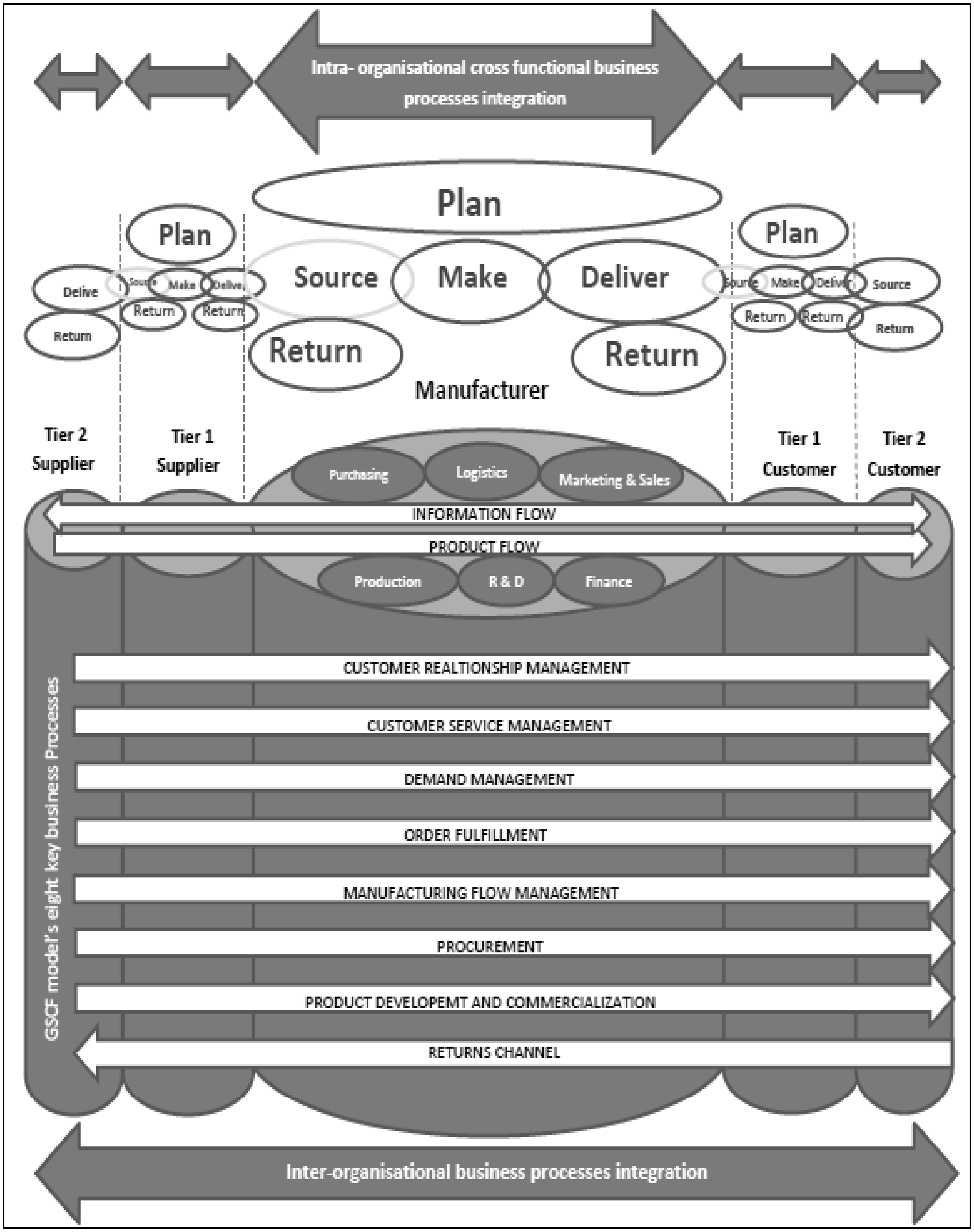
GSCF model identified eight key business processes that can be linked across the SC. The number of business processes to integrate and manage varies between companies. Companies should decide the critical business processes from these eight key business processes that should be managed and integrated with different members within the SC. The other two elements of GSCF model (SC network structure and SC management components) represent the key elements of achieving successful SCM integration using the model's eight key business processes. The GSCF model's SC network structure allows identifying the key SC members with whom a company should link these key business processes. While, the GSCF model's SC management components identify the level of integration and management that should be applied for each process link (Lambert et al., 1998; Croxton et al., 2001). Figure 2.1 illustrates SCM integration within organisation and across the SC based on SCOR and GSCF frameworks.

As demonstrated in figure 2.1, the SCOR model maps the entire SC processes to standardised processes workflows based on five core processes (plan, source, make, deliver and return). The

SCOR framework provides standardised business processes by which companies can accomplish cross functional integration between different organisational functions (R&D, purchasing, production, marketing & sales, logistics and finance). Mapping the entire SC processes to the SCOR's standard description of SC processes enables the individual members of the chain to have unified description and understanding of their SC processes as a prerequisite of SCM integration across the SC.

On the level of SC network integration, figure 2.1 shows how the GSCF model's eight key business processes are designed to integrate companies' internal activities with other members of the SC. The GSCF framework provides the elements by which a company can identify: the SC key members with whom it is critical to link, the processes to be linked with each of these key members and the type/level of integration that applies to each process link.

Once the appropriate supply chain framework is determined, the next step in developing a SC performance measurement system is to decide how the SC performance benchmarking process will be designed and implemented. According to Beamon (1999), benchmarking is an important step in developing an appropriate SC performance measurement system as it can serve as a method of identifying SC performance improvement opportunities. The next section provides an insight into the evolution, definition, process, types and levels of benchmarking, then it discusses the application of benchmarking in a SC context.



(Developed from: Lambert and Cooper, 2000; and SCOR Model - Version 9, Supply Chain Council, 2008)

Figure 2.1: SCM integration within organisation and across the SC

2.4.3 Benchmarking SC operations' performance

Several researchers have studied strategies such as benchmarking, total quality management and reengineering as alternatives for improving business processes performance, while other researchers have integrated them (Drucker, 1994; Peter, 1994). Since the early 1980's, the application of benchmarking have been widely studied in different business areas such as marketing, human resources, accounting and supply chains (Meybodi, 2008). It started to be used as a tool to improve organisations' performance and competitiveness in a business sector. In 1983, Xerox made competitive benchmarking a fundamental part of their operations. In order to regain their strategic advantage against severe international competition, Xerox benchmarked the performance of more than 230 processes in their operations through identifying the best processes performed by competitors and adjusted them according to Xerox's processes (Lankford, 2000).

Both managers and academics have developed several definitions for benchmarking according to their own perceptions and applications of this technique (Fernandez et al., 2001). In summary, benchmarking means the continuous measuring of company's performance against competitors or industry leaders (best in the class) in order to discover the gap in a company's performance and then analyse the strengths and weaknesses of the company in order to identify key improvement areas and search for applicable solutions to enhance the company's operations performance (Peter, 1994; Lankford, 2000; Fernandez et al., 2001; Moffett et al., 2008).

Peter (1994), Leandri (2001) and Jones (2004) illustrated a five-step methodology describing how benchmarking process should be designed and implemented. The methodology starts with setting the plan through: identifying what is to be benchmarked and against whom and determining the data collection method. Then the data required for benchmarking is collected, including secondary (publicly available) data and primary (collected directly from the selected benchmark partner) data. The data collected is analysed in order to identify the performance gap between the company and the benchmark and determine the improvement actions. An action plan for performance enhancement is developed and implemented and finally, the progress is monitored.

Several types of benchmarking can be used such as process benchmarking, performance benchmarking and financial benchmarking, however the critical issue is to determine which types of performance measures can be used in relation to benchmarking. The main benchmarking types are illustrated below (Peter, 1994; Lankford, 2000; Fernandez et al., 2001; Leandri, 2001):

- Process benchmarking: focuses on the day-to-day operations of the organisation to improve the way processes are performed every day.
- Performance benchmarking: focuses on assessing competitive positions through comparing the products and services with those of competitors.
- Financial benchmarking: focuses on assessing the financial position through comparing a company's financial analysis results with those of competitors.
- Functional benchmarking: focuses on benchmarking specific functions in order to improve them, such as human resources, accounting and finance and information technology.
- Generic benchmarking: focuses on benchmarking the company's whole process. This type applies to the processes and functions that are comparable across organisations which may be in different industries.

- Strategic benchmarking: focuses on how companies compete. This type aims at improving overall performance through examining the long term strategies that a company uses compared to its competitors.

In addition to selecting the appropriate type of benchmarking to be applied, designing and implementing a benchmarking process requires consideration of the level at which benchmarking can take place. Benchmarking can be applied at several levels (internal level, competition level, best in industry level or international level). The selected benchmarking level should be relevant to the focus and the purpose of the benchmarking process. Table 2.5 summarises the differences between different levels of benchmarking through discussing the focus, the advantages and the limitations of applying each level.

Table 2.5: Different levels of benchmarking

Level of benchmarking	Focus	Advantages	Disadvantages
Internal	Identify the best practices within the company departments, business units, sister companies and disseminate these practices throughout the organisation.	- Relatively easy to accesses sensitive data and all information required. - Cost effective benchmarking approach as less time and resources needed to accesses required information. - Allows managers in the organisation to be more knowledgeable about the organisation as a whole.	Missing the bigger picture as even the best internal practices might not be the best in the class.
Competitor	Benchmark the performance of the company against its direct competitors.	Leads to effective solution and productive changes and results.	- Difficult to access information as organisations are not interested in helping a competitor by sharing information. - Determine which competitors perform better can be easy task for low performance companies; however it is difficult to high performance companies as they have fewer competitors worth benchmarking against.
Best in industry	Benchmark the performance of the company against the leader in its sector.	Provides best practices to enhance company's operations performance.	Difficult to access information. since other companies in the sector are also wish to contact the leader company; competition among companies to gain benchmark against the leader in the sector will be intense

International (world class)	Comparing company's performance against the best of the world.	- Suitable when organisation has too few benchmarking partners within the same country or when it provides a unique service or product and there are no organisations within the country to be benchmarked against. - provides innovative ways for improving performance and dealing with problems.	- Having different external business environment may affect the validity of results. - Involves higher costs and more complexities.

(Adapted from: Peter, 1994; Helgason, 1997; Lankford, 2000; Fernandez et al., 2001; Jones, 2004)

To sum up, the main idea behind benchmarking is to identify best practices, study these practices, make plans for improving the performance, implement them and finally, monitor and evaluate the results. In short: benchmarking is to identify and implement best practice (Helgason, 1997).

Benchmarking in supply chains commenced in the mid 1990s. The initial approach to model supply chain benchmarking focused on addressing performance measures and later moved into applying benchmarking in an integrated perspective. Compared to other fields, benchmarking in the supply chain context involves complex relationships and unknown tradeoffs between multiple inputs and multiple outputs. The most critical issue in the supply chain benchmarking process is to define the appropriate performance measures and the integration among them in order to establish the correct metrics to measure a company's performance (Wong and Wong, 2008).

Although several approaches have been proposed by researchers to model supply chain benchmarking, some gaps concerning supply chain benchmarking research still exist. There is a need to develop an adequate methodology to determine the relative importance of performance measures, which varies among companies and then to aggregate them into a single index of overall performance from which a company can compare its SC performance with other industry members(Simatupang and Sridharan, 2004a, b; Wong and Wong, 2008).

2.5 Links between supply chain performance and a company's financial performance

Although the impact of SCM on a company's performance has been discussed by many researchers, few studies have been conducted to find the links between SCM practices and financial performance improvements (Gardner, 2004). According to Camerinelli and Cantu' (2006), still there is no direct and clear link between the measurement of day-to-day supply chain operations and the overall financial performance of the chain. Supply chain performance and the organisation's financial performance have been widely studied but limited empirical affirmation of their relationship has been presented (Toyli et al., 2008). In this section, a chronological review is conducted on the links between supply chain performance and financial performance.

Between 1997 and 2000 a join research team from Accenture, INSEAD and Stanford University studied the supply chain-financial performance link. The study aimed to test the statistical relationship between companies' financial success and the performance of their supply chains. Publicly available data for 3,000 companies was statistically analysed and in-depth interviews conducted with more than 75 executives from 60 companies. A web-based survey, designed to capture the supply chain insights and experiences of leading executives from companies across North America and Europe, also yielded 100 responses. The study's results were published in 2003 showing a statistical correlation between companies' financial success and the performance of their supply chains. According to the study's results, supply chain leaders accomplish significantly higher market-capitalisation growth rates than the industry average growth rate. Moreover, analysis of the study's interviews and surveys revealed that successful business strategies of leading companies incorporate supply chain strategies that provide competitive advantage and devote significant attention to designing integrated supply chain operating models (D'Avanzo et al., 2003).

Deloitte (2003) conducted a study of 600 companies in 22 countries which concluded that effectively managing a complex global supply chain has a positive impact on a company's financial performance (as cited in Colman, 2003). The study revealed that companies which effectively managed their supply chain realised profit margins 73% higher than other companies with poor supply chain performance and less complex environments.

Gunasekaran et al. (2004) conducted a survey to study the performance measures and metrics used in a supply chain environment. The survey investigated the impact of implementing SCM practices on enhancing return on investment. The results revealed that 76% of responses showed that practices of carefully managed supply chains resulted in financial benefits for participating companies.

Presutti Jr. and Mawhinney (2007) demonstrated how supply chain metrics can be linked to corporate financial metrics to achieve the critical link between supply chain performance and business performance. The supply chain performance metrics used were based on the Supply Chain Operations Reference-model (SCOR), while the financial metrics used were based on the Economic Value Added (EVA) concept. The study concluded that there is a clear and direct link between how effectively supply chain activities are executed and how well the business performs. The success in making this link between corporate performance and supply chain performance results in satisfying two of the company's most important stakeholders - its customers and shareholders.

Tejas and Srikanth (2007) linked supply chain metrics to financial key performance indicators through using scorecards to determine priorities for investments in improving processes and related technology. This linkage helps senior managers to quantify the performance of SC metrics and understand its impact on the organisation's top and bottom lines.

Toyli et al. (2008) analysed the relationship between logistics performance and financial performance in Finnish small and medium-sized enterprises (SMEs). The study comprised 424 SMEs that participated in a nationwide Finnish logistics survey in 2006. Logistics performance measures were derived from the survey data and classified into three dimensions: service level characterising the service quality, operational metrics characterising the time-based logistics performance and logistics costs characterising cost efficiency. The financial performance of these companies was then examined in terms of growth and profitability using financial reports-based data. The results implied that there was no positive linkage between logistics performance and financial performance among the surveyed companies, indicating that logistics is just starting to gain more attention among SMEs in Finland and that it might be relatively easy for SMEs to gain competitive advantage by focusing more on logistics performance.

Woei (2008) conducted research to explore the supply chain management- financial success relationship. To analyse the relationship between a company's financial success and its supply chain performance, an empirical study was undertaken based on financial information extracted from public quoted companies in Malaysia during the financial years from 1999 to 2006. Financial success was measured by market capitalisation while supply chain performance was measured by four variables namely revenue, cost of sales as percentage of revenue, cash to cash cycle and return on working capital. The data was statistically analysed to test the correlation between categories of SCM performance measures and financial success. The results showed that the correlation was weak for the financial years of 1999 to 2002, while the correlation became stronger for the subsequent financial years of 2003 to 2006. The results also revealed that companies which implement the full scope of supply chain measures can find opportunities to become financially successful companies in the today's business environment.

Camerinelli (2009) illustrated the link between financial performance and operational decisions through mapping financial metrics to operational metrics. Since operational metrics assess the operational status of the company and are linked to operational decisions, a company's financial performance can reflect the quality of the operational decisions taken to accomplish it. The researcher identified the operational metrics that can be used to map financial metrics to operational metrics based on the SCOR model standard performance metrics through selecting the proper elements from the balance sheet and income statement to be linked to the SCOR level 1 and level 2 metrics.

Hutchison et al. (2009) suggested how cash-to-cash strategies can be used in a supply chain environment as effective cash management and synergistic tools to realise opportunities for improving efficiency, profitability, cash flow management and communication channels among supply chain members. According to this approach, an information-sharing environment should be established among trading partners in the supply chain in order to identify possible opportunities that can ultimately improve cash flow and profitability. The cash-to-cash calculation includes three financial variables: inventory, accounts receivable and accounts payable. Since each party in the supply chain may have an advantage in its weighted average cost of capital or inventory carrying cost, the chain can manipulate inventory as well as receivable and payable terms to reduce costs that relate to purchases, inventory and capital in order to benefit all trading partners throughout the supply chain.

Kremers (2010) proposed an approach that provides a comprehensive vision of the existing relationship between companies' operational and financial performance. According to this approach, supply chain operational performance can be evaluated in terms of its impact on cash flow, market value and key internal financial performance metrics. This approach tied SC operational performance to strategic business goals through linking SCOR model performance measures to the priorities of financial performance drivers (profitability, asset utilisation and financial leverage efficiency).

Marquez (2010) developed and evaluated a comprehensive dynamic SCM model to determine operational and financial benefits from various levels of supply chain integration. The model highlighted the financial implications of different pricing strategies and cost structures when modelling financial aspects of the supply chain. It explored the operational and financial impacts of various potential problems in SCM, offering a compilation of practical solutions using system dynamics.

Ou et al. (2010) conducted an empirical research on the relationship between SCM practices and a company's performance. The study explored a structural model connecting the relationships among external customer-firm-supplier integration, internal contextual factors (human resource management, quality data and reporting, design management and process management) and firm performance. The model identified the relationships among SCM practices and highlighted the importance of customer-firm-supplier integration to improve firm internal contextual factors and firm performance. The results revealed that successful implementation of SCM positively impact on a company's financial performance resulting from the achievement of better customer satisfaction.

Wisner (2011) argued that SCM decisions and resource utilisation could impact the financial performance of the company. To demonstrate such impact, Wisner illustrated how SC functions influence the results shown in the company's financial statements (Income Statement, Balance Sheet, Statement of Cash Flows and Statement of Stockholders' Equity). She introduced a linkage model linking SC performance metrics to the outcomes of the financial statements. The model identified the SC performance measures relevant to the components of each financial statement in order to ensure that supply chain actions and decisions are compatible with the company's financial goals.

Wagner et al. (2012) investigated and quantified the relationship between supply chain fit and the financial performance of the firm. A multi-country, multi-industry survey sample of 259 manufacturing firms from the USA and Western Europe was conducted to empirically validate the positive impact of (or the lack of) supply chain fit on the financial performance of the firm. Supply chain fit was measured in terms of strategic consistencies between the products' supply and demand uncertainty and the underlying supply chain design, while the financial performance of the firm was measured using Return on Asset (ROA) ratio as an outcome of supply chain fit (or misfit). The resulted indicated that the higher the supply chain fit, the higher the ROA of the firm. The findings revealed that firms with a negative misfit showed a lower performance than firms with a positive misfit which highlighted the strategic relevance of supply chain management in the firm and its tangible implications on the financial performance.

Although the above review revealed links between SCM practices and financial performance improvement, the concept and application of this idea is still immature in the literature. Most studies concerning links between supply chain performance and a company's financial performance have focused only on testing the statistical relationship between a company's financial performance and its SC processes' performance (D'Avanzo et al., 2003; Deloitte, 2003; Gunasekaran et al., 2004; Toyli et al., 2008; Woei, 2008; Wagner et al., 2012).

Few studies have been conducted to find the links between SCM practices and improvements in financial performance (Tejas and Srikanth, 2007; Camerinelli, 2009; Hutchison et al., 2009; Kremers, 2010; Marquez, 2010; Ou et al., 2010; Wisner, 2011) and they did not achieve the critical link between supply chain performance and business performance. Most of these studies did not describe the applied methodology in detail or did not cover all business dimensions nor incorporate different levels of decision making (strategic, tactical and operational). This consequently leads to the need for creating a framework which can capture the direct and clear link between the SCM practices and improvements in financial performance.

2.6 Discussion and Conclusion

This chapter began by reviewing the literature on performance measurement and how performance measurement systems developed from traditional financial performance measurement systems to integrated performance measurement systems incorporating financial and non-financial measures. The review focused on SC performance measurement and identified the main problems of current SC performance measurement systems. The chapter also provided an insight on the design and implementation of a performance measurement system in a supply chain context. In addition, the link between SC processes' performance and a company's overall financial performance was reviewed accordingly, where process focused SC measurement systems were highlighted, especially the SCOR model and the GSCF model.

This review revealed that performance measurement systems can be used as a strategic tool that enables companies to evaluate, manage and continuously control the entire set of operations in order to achieve their objectives and goals. A well-designed performance measurement system is essential for improving business processes. In recent years, attention has increased on how to design and implement an effective performance measurement system. Traditional financial performance measurement systems do not keep pace with today's business environment. The new business environment requires performance measurement systems that incorporate financial and non-financial measures.

However, there is no unique performance measurement system that can be applied to any company as the process of developing a strategic measurement system needs to be tailored to each individual company. Designing and implementing a performance measurement system is a function to a company's strategic position and objective, its culture and the complexity of its business processes. The review illustrated the main aspects that should be considered when designing and implementing a SC performance measurement system. First, the characteristics, the structure and the strategy of the targeted supply chain should be analysed. Then, the appropriate supply chain framework is selected. Finally, supply chain performance benchmarking process is designed and implemented.

Although various SC performance measures and metrics were proposed, there is still a need for further research to develop a fully integrated supply chain performance measurement system. The existing supply chain performance measurement systems have limitations in coping with the overall business strategy and creating the integration between financial and non-financial measures. Today’s business environment requires a shift towards implementing process focused SC measurement systems.

The need to implement a cross-functional business processes performance management system has now been recognised. Several studies have been developed to provide a framework for analysing supply chains from a more integrated standpoint (Tipi et al., 2008). The SCOR and the GSCF models provide standardised business processes frameworks which can be considered as a foundation for future research to develop integrated process focused SC measurement systems within organisations and across the SC.

The frameworks of the SCOR model and the GSCF model can be integrated and linked to achieve both organisational and SC network integrations. The successful SCM integration across the SC requires an information-sharing environment among its members in order to identify possible opportunities that can benefit all members throughout the supply chain. The GSCF framework focuses on aligning SC processes with organisational and functional strategies through customer and supplier relationship management which makes the framework relationship-oriented.

On the other hand, SCOR processes focus on the operations strategy through identifying areas of improvement in order to provide cost reductions and improve asset efficiency. The operational focus of SCOR framework allows translating the entire SC processes - with their focus on day to day operations- into financial targets through aligning the company's SC resources and goals with the strategic financial objectives.

Figure 2.1 presented a SC which had two tires of suppliers, two tiers of customers and a focal company. The figure introduced the SCOR model framework with its five core processes (plan, source, make, deliver and return) to achieve intra-organisational cross functional business processes integration by which integration of business functions (R&D, purchasing, production, marketing & sales, logistics and finance) can be accomplished. The figure also introduced the

GSCF model's eight key business processes to accomplish inter-organisational business processes integration with other members of the SC.

This research focuses on enhancing the financial performance within a manufacturing company through managing its entire SC operations. Thus, SCOR framework can be employed to achieve intra-organisational cross functional SC business process integration in order to improve the performance of the entire SC operations as an intermediate step towards enhancing the company's financial performance. An example of how SCOR model can be employed to achieve intra-organisational cross functional business processes integration is introduced and explained in Appendix 5. The example demonstrates the implementation of cross functional business process integration within a company based on the SCOR model standard description of SC processes at different levels of processes details (see figure A5.2).

In addition to mapping and integrating SC processes, SCOR model allows evaluating the performance of these processes and tracing processes that need improvement. As mentioned earlier, SCOR model provides a hierarchy of standard performance metrics to measure the performance of SCOR standardised processes at different levels. The SCOR model standard performance metrics will be discussed in detail in chapter three.

The literature also highlighted the significant relationship between financial performance and supply chain performance, however few studies have been conducted to investigate the links between SC performance and financial performance improvements. The review revealed that previous studies in this area failed to develop an applied framework capturing the critical link between an organisation's SC operational strategy and its business performance.

Intra-organisational integration is an essential primary step for companies to adopt and implement SCM or inter-organisational integration. Although previous studies in the area of

SCM confirmed the positive effects of SCM on an organisation's performance as an outcome of the integration of business processes internally and externally, empirical evidence to develop a theoretical base for the establishment and execution of SCM within a company is still lacking (Kotzab et al., 2011). Case-based studies to analyse the impact of managing SC operations' performance on enhancing a company's overall financial performance are worthy of investigation.

In developing countries such as Egypt, there is still a lack of understanding the link between a company's financial performance and supply chain performance. Paying attention to this link represents an opportunity for companies in these countries to gain competitive advantages through focusing more on supply chain performance management.

CHAPTER THREE - RESEARCH METHODOLOGY

3.1 Introduction

In the previous chapter, a review of related literature was conducted on the different methodologies used in measuring SC performance and linking it to a company's financial performance. Based on this review, the appropriate methodology for this study was selected and is presented in this chapter. A technique derived from Theeranuphattana and Tang (2008) is proposed to analyse, assess and improve the performance of SC operations. Then, a performance measurement method developed from Presutti Jr. and Mawhinney (2007) will be introduced to link SC operations' performance to a company's financial strategy.

This chapter commences by defining the scope of this research, upon which the research philosophy, approach and strategy are selected. The research follows a deductive research approach incorporating both the quantitative and qualitative research methodologies whereby a deductive qualitative case is conducted for the development and validation of the research framework. An insight on the design and implementation of case study research method is provided in this chapter. The chapter thoroughly discusses the methods, models and techniques used in creating the framework for measuring SC performance and linking it to a company's financial performance: the SCOR model, the fuzzy analytic hierarchy process (FAHP) technique, Du Pont ratio analysis and the Dempster Shafer/Analytical Hierarchy Processes (DS/AHP) model. The rationale of combining the SCOR model and the FAHP technique for measuring SC operations' performance and the rationale for incorporating Du Pont analysis in the financial performance metrics are illustrated in this chapter. The chapter finally concludes by presenting the conceptual framework of the research methodology.

3.2 <u>The scope of the research</u>

Companies increasingly compete through the strength, resilience and flexibility of their supply chains (Christopher, 1992; Rice Jr. and Hoppe, 2001; Groznik and Maslaric, 2010). Cooper et al. (1997), indicated that prior to 2000s several studies have recommended various ways to optimise the supply chain, such as: synchronizing the requirements of the customer with the flow of material from suppliers; reducing the inventory investment in the chain; increasing customer service; and building competitive advantages for the supply chain. However, the importance of a total supply chain management perspective and the need to integrate and manage multiple key processes within and across companies has been ignored (Lambert and Cooper, 2000).

Mentzer et al. (2001, p.18) defined SCM as "*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.*"

In the 2000s, researchers began to pay attention to supply chain management and performance measurement as these topics emerged at the forefront of the operation management (OM) research agenda (Pilkington and Fitzgerald, 2006; Craighead and Meredith, 2008; Pilkington and Meredith, 2009; Taylor and Taylor, 2009).

Studies in the OM field have witnessed remarkable progress in the quantity and quality of empirical research (Rungtusanatham et al., 2003). Bertrand and Fransoo (2002, p.241) defined OM as "*the process of design, planning, controlling and executing operations in manufacturing* *and service industries*". Due to the similarities and inter-relationships of OM field and operational research (OR) field, researchers in the OM field have challenged the convergence and overlap between the two fields at the conceptual and techniques levels (Fuller and Mansour, 2003). OM deals mainly with managerial and activity aspects in the business environment while OR focuses on technical and mathematical issues (Anderson et al., 2002). OM focuses on the modelling of operational processes to describe the statics and dynamics of the processes, whereas OR pertains to the analysis of the mathematical aspects and the quality of the mathematical solutions which are derived from the model in order to be implemented in real-life problems. Therefore, OR can be considered as part of the quantitative research in operations management (Bertrand and Fransoo, 2002).

Measuring the performance of supply chains can facilitate the integration between supply chain partners and contribute to decision making in SCM, especially in redesigning business goals and strategies. Moreover, evaluating the performance of SC operations can help to assess the current SC operations' performance in order to identify core competence operations and those operations which need improvement (Chan and Qi, 2003a; Charan et al., 2008).

SCM practices have significantly impacted on a company's performance. Understanding supply chain relationships represents a key driver of a company's performance (Kannan and Tan, 2005).

To effectively measure the impact of SC activities on the company's overall financial performance, SC performance needs to be linked to the company's strategic financial goals (Kremers, 2010). The challenge for many companies is that the alignment of performance measurements between SC and financial functions is still rather poor. The main reason for this is that supply chain performance metrics and financial performance metrics are defined in different ways which creates difficulty when translating SC operational measures, with their focus on day to day operations, into financial targets (Camerinelli and Cantu', 2006).

The primary long-term financial goal of the company is to maximise profit. To accomplish this overall long-term goal, the company should translate it into meaningful short-term performance objectives that can be measured and monitored. These objectives can be achieved through identifying the source of poor performance in terms of specific activities and formulating short-term strategies for improving the performance of these activities (Grant, 2005). This consequently leads to the need for understanding the link between SC performance metrics and the overall metrics used to measure the company's financial performance in order to align SC processes' performance to the company's strategic financial goal.

Therefore, this study will create a framework to align supply chain operational strategy and the company's overall strategy through linking supply chain operations' performance to the company's financial performance in the manufacturing sector. This framework aims to:

- Propose a technique to analyse, assess and improve the performance of SC operations.
- Develop a performance measurement method to link SC operations' performance to a company's financial strategy and then examine the impact of managing supply chain operations' performance on enhancing the financial performance of a company.

By having this framework, manufacturing companies can evaluate, monitor and control SC operations' performance in order to optimise the company's short-term strategic financial objectives. Linking SC operations' performance to these objectives enables companies to formulate operational strategies for improved SCM through linking such strategies to the focus area of enhancing the financial performance.

The framework will be derived from the model proposed by Theeranuphattana and Tang (2008) to identify and employ SC performance measures and the method introduced by Presutti Jr. and Mawhinney (2007) to achieve the critical link between supply chain performance and business performance that were discussed in chapter two. Table 3.1 shows the stages of creating the framework for measuring SC performance and linking it to financial performance in the manufacturing sector. The research methods, models and techniques used at each stage are illustrated in table 3.1 (i.e. the SCOR model, the FAHP technique, Du Pont ratio analysis, DS/AHP model and case study) and will be discussed later in further detail in addition to the rationale of combining them to create the framework. The next section will discuss the research philosophy, approach and strategy conducted in this study.

Table 3.1: Stages of creating the research framework

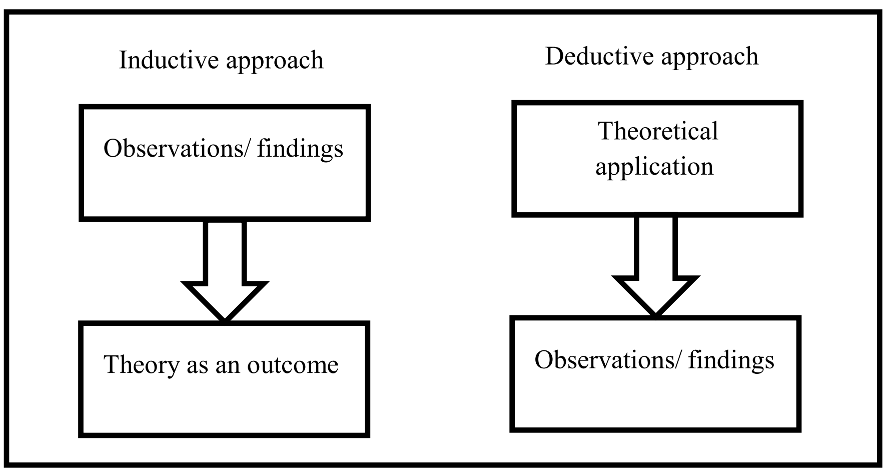
Research stage	Research methodology	Used model/method/technique	Out put
Proposing SCOR FAHP technique	Proposing a technique which incorporates the FAHP technique and SCOR model to analyse, assess and improve the performance of SC operations.	SCOR model	Mapping SC processes and identifying the corresponding performance measures for the mapped processes.
		The FAHP technique	Determining the relative importance weights of SC performance measures.
Developing a performance measurement method	Developing a performance measurement method to link SC operations' performance to a company's financial strategy through demonstrating and utilising the relationship between SC operations' performance and a company's financial performance.	Du Pont ratio analysis	Evaluating a company's overall financial performance and identifying financial performance factors that need improvement.
		DS/AHP model	Linking SC operations' performance to the priorities of financial performance factors through determining the relative importance weights of the main supply chain performance measures with respect to these priorities.
Conducting a case study	A single holistic case study of an Egyptian manufacturing company will be conducted.	Case study	Demonstrating the applicability of the research methodology.

3.3 Research philosophy, approach and strategy

Understanding the relation between research philosophy, approach and strategy is essential for any research. Easterby-Smith et al. (2002) stated three reasons why an understanding of philosophical issues and approaches to research is very useful. Firstly, it allows the researcher to clarify research designs. Secondly, knowledge of philosophy can help the researcher to understand and recognise which designs can be more appropriate and work best in terms of the type of evidence required and how it can be collected and interpreted. Finally, it enables the researcher to identify and adapt research designs according to the constraints of different knowledge structures. In addition, knowledge of research philosophy and approaches can provide useful insights on the development of a theory, which is often made implicit in the design of the research (Pathirage et al., 2008). In this section, different research philosophies, approaches and strategies are generally explained. Then, an insight on OM research is provided. Finally, the research philosophy, approach and strategy conducted in this study are clarified.

The two most well-known research philosophies are positivism and interpretivism (Saunders et al., 2007). According to Easterby-Smith et al. (2002), determining which should come first, the theory or the data, represents the main issue to guide the research towards the appropriate research philosophy (positivism or interpretivism). Positivism considers that the research phenomena are objectively determined where the researcher is detached and independent, having minimum interaction with the research participants. It applies empirical research following a strict set of guidelines, and thus the analysis of observations is likely to be quantifiable. Unlike positivism, interpretivism is concerned with subjective, qualitative phenomena where the researcher is actively engaged in the research through high levels of interaction and/or participation (Wilson, 2010).

Positivism and interpretivism philosophies are also differentiated by their implications for the research approach to be adopted (deductive or inductive). Positivism is usually based on a deductive approach, while interpretivism is usually carried out based on an inductive approach (Young, 2007). The inductive approach is a theory building process based on the empirical data collected in a situation where there are few or no theoretical preconceptions. It starts with observations from the empirical world and seeking to establish generalisations about the phenomenon under investigation in order to construct the theory. This approach is often associated with qualitative research methods. The deductive approach is a theory testing process starting with the development of hypotheses from existing theories, which are then tested against the data collected to see if the theory applies to specific instances. This approach is often associated with quantitative research methods (Hyde, 2000; Young, 2007; Pathirage et al., 2008).



(Source: Wilson, 2010)

Figure 3.1: The role of theory in inductive and deductive research

Figure 3.1 illustrates the role of theory in each approach. A deductive approach develops hypotheses based on existing theory and then designs the research strategy to test the hypotheses. On the other hand, an inductive approach collects data, then develops theory based on data analysis (Wilson, 2010). Table 3.2 summarises major differences between deductive and inductive research approaches.

Table 3.2: Major differences between deductive and inductive research approaches

Deduction emphasises	Induction emphasises
• Scientific principles • Moving from theory to data • The need to explain causal relationships between variables • The collection of quantitative data • The application of controls to ensure validity of data • The operationalisation of concepts to ensure clarity of definition • A highly structured approach • Researcher independence of what is being searched • The necessity to select samples of sufficient size in order to generalise conclusions	• Gaining an understanding of the meanings human attach to events • A close understanding of the research context • The collection of qualitative data • A more flexible structure to permit changes of research emphasis as the research progresses • A realisation that the researcher is part of the research process • Less concern with the need to generalise

(Source: Saunders et al., 2007)

An important issue arising from the above comparison between the two approaches is the appropriateness of qualitative versus quantitative research methods. As illustrated in table 3.2, a qualitative strategy is usually linked with an inductive study, while quantitative strategy is usually associated with a deductive approach. Quantitative research examines numerical data to determine certain facts, or correlations between facts. It enables the conducting of research on a broad scale since statistical analysis is usually used to construct generalisation regarding the population as a whole. Qualitative research examines narrative data thus it is relevant when the research goal is to explore a wide range of dimensions associated with a particular topic. It explores topics in greater depth and detail than quantitative research but may have limited generalisation compared to quantitative methods (Young, 2007; Wilson, 2010).

However, there is no universal superior research methodology as each research strategy has its benefits and limitations. Quantitative and qualitative strategies are not mutually exclusive as commonly they are combined while the superior of one to the other depending on the circumstances and the aim of the study (Kiridena and Fitzgerald, 2006; Wilson, 2010). The key distinctions between quantitative and qualitative research methods are illustrated in table 3.3.

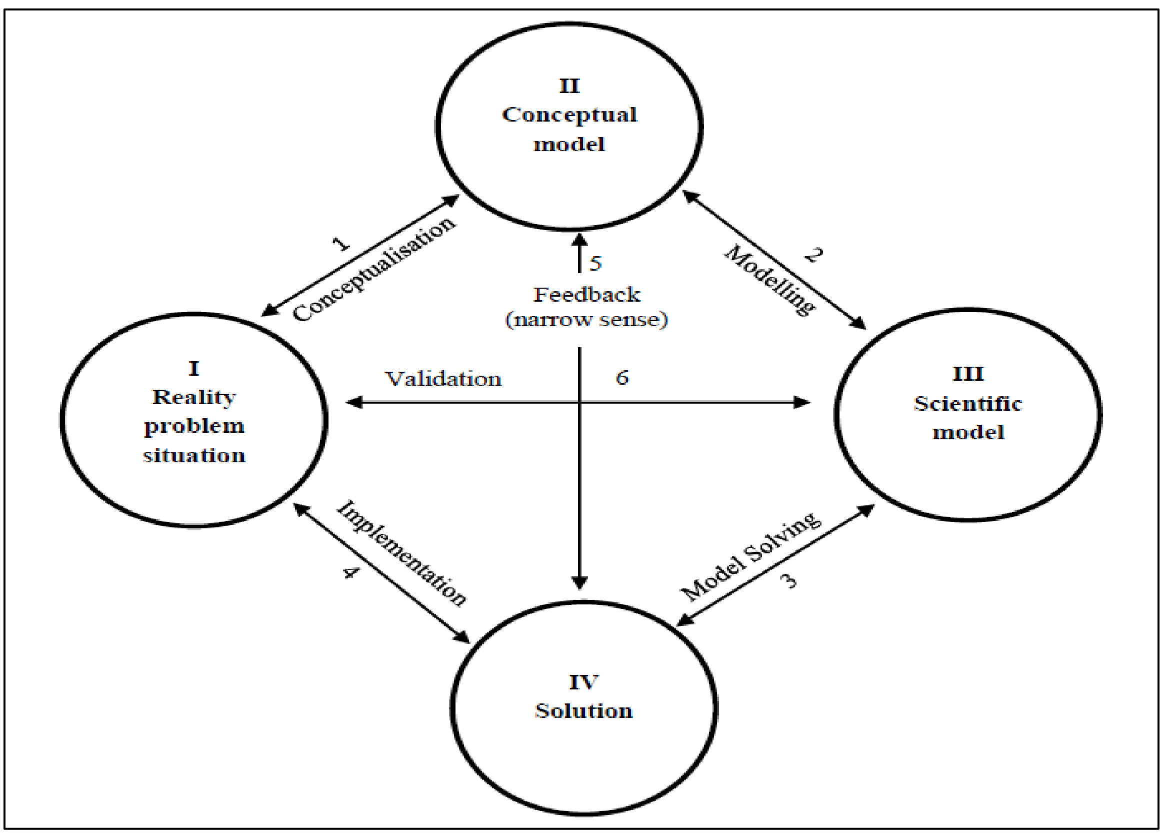
Table 3.3: Qualitative versus quantitative research methods

	Qualitative Methods	Quantitative Methods
Basic beliefs about the nature of reality	▪ There are multiple realities; reality is not purely objective, and does not exist independent of the people who interpret it	▪ There is one objective reality that is not dependent on human interpretation
Main paradigms	▪ Interpretivism	▪ Positivism
Common research methods	▪ Grounded theory ▪ Action research ▪ Ethnography ▪ Case study	▪ Experiment ▪ Survey
Quality assurance	▪ Construct validity, confirmability, internal validity/credibility, external validity/transferability, reliability/dependability ▪ Sampling: purposeful	▪ Reliability: internal and external ▪ Validity: construct, context ▪ Sampling: random and deliberate
Key differentiating characteristics	▪ Primarily inductive process used to formulate theory	▪ Primarily deductive process used to test pre-specified concepts, constructs, and hypotheses
	▪ More subjective: describes a problem or condition from the point of view of those experiencing it	▪ More objective: provides observed effects (interpreted by researchers) of a problem or condition
	▪ Text-based	▪ Number-based
	▪ In-depth information on a few cases	▪ Less in-depth but more breadth of information across a large number of cases
	▪ Unstructured or semi-structured response options	▪ Fixed response options
	▪ No statistical tests	▪ Statistical tests used for analysis
	▪ Can be valid and reliable: largely depends on skill and rigour of the researcher	▪ Can be valid and reliable: largely depends on the measurement device or instrument used
	▪ Less generalisable	▪ More generalisable

(Source: Liouka, 2007)

Sagasti and Mitroff (1973) proposed a conceptual model of the operations research process by adopting general systems theory with a holistic point of view upon which OR can be understood and effectively applied. The model had five components: the reality of the problem situation, the conceptual model of the problem situation, the scientific model of the conceptual model, the solution to the scientific model and the implementation of the solution.

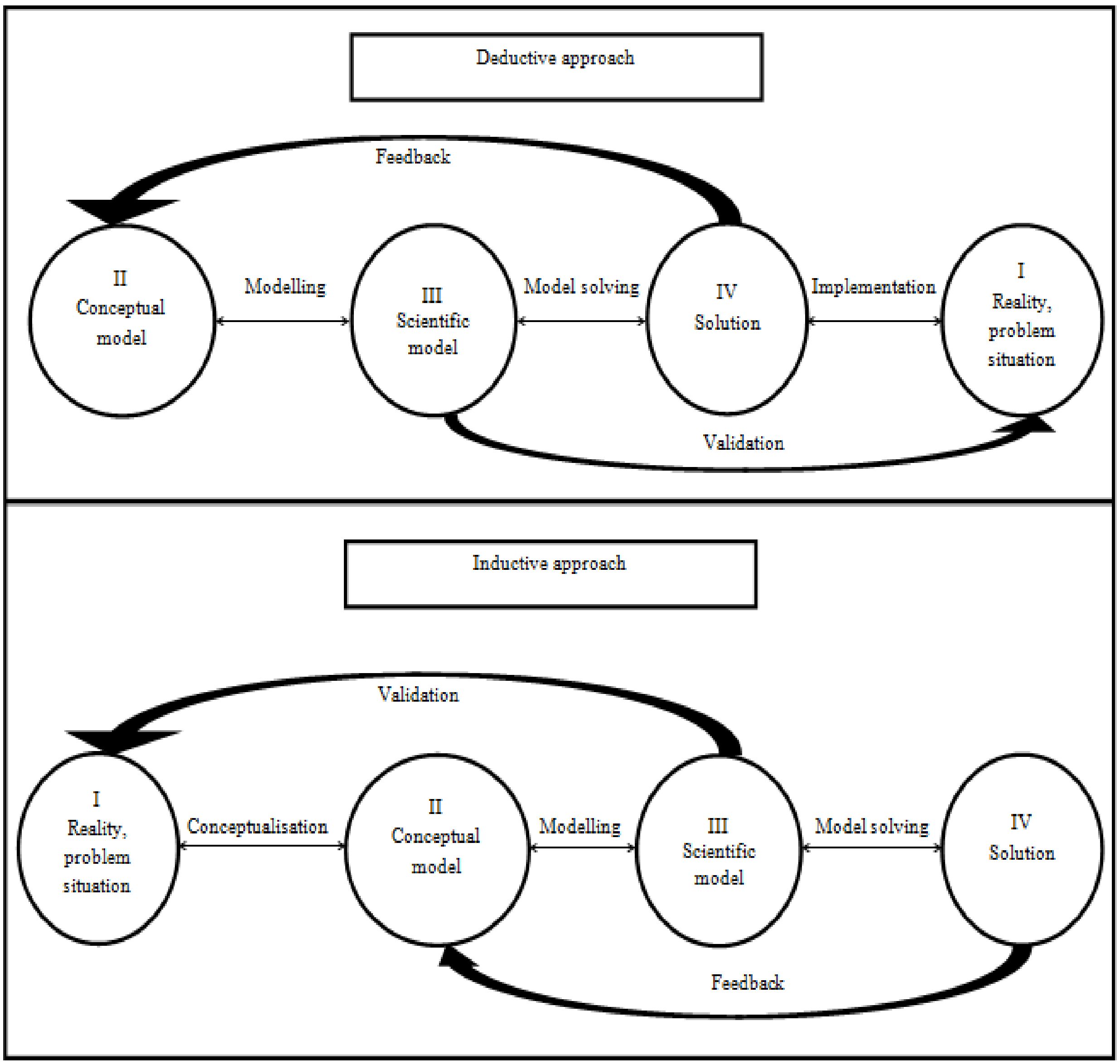
This model was further developed by Mitroff et al. (1974) who extended it to cover diverse research styles. The initial model proposed that every scientific inquiry starts with the existence of a problem situation. The conceptual model was then formulated through identifying the particular problem that will be solved and its variables. Based on the formulated conceptual model, a scientific or formal model can be formed, then a solution can be derived and then implemented. As shown in figure 3.2, the extended model showed that there are no starting or ending points as the research process can begin at any point in the diagram. Different research approaches adopt different loops in terms of various combinations and flows of these points.



(Source: Mitroff et al., 1974)

Figure 3.2: A systems view of problem-solving

In deductive approaches, the appropriate loop will be "II, III, IV and I", where the scientific model is formed from the existence of a prior or given conceptual model and then the solution is derived and implemented for validation. In inductive studies, the appropriate loop will be "I, II, III and IV", where the theory is constructed based on the recognition of a problem situation (see figure 3.3).



(Adapted from: Mitroff et al., 1974)

Figure 3.3: Systems view of different research approaches

The previous discussion demonstrated the relationship between research philosophy, approach and strategy. A positivist philosophy is usually based on a deductive approach and associated with a quantitative strategy, while interpretivism philosophy is usually carried out based on an inductive approach and linked with a qualitative research strategy (see table 3.4). While this distinction is true in general as it helps researcher to decide which direction is appropriate, it can be ambiguous in practice. Following the therotical alignment between research philosophies, approaches and strategies limits and confuses the research process. The chosen area of research can influence the researcher to not fully adopt the theoretical distinction between research approaches. In practice, an inductive approach can involve quantitative methods and a deductive approach may involve qualitative methods (Hyde, 2000; Knox, 2004; Wilson, 2010).

Table 3.4: The relationship between research philosophy, approach and strategy

Research philosophy	**Research approach**	**Research strategy**
Positivism	Deductive	Quantitative
Interpretivism	Inductive	Qualitative

In OM research area, quantitative research methods such as quantitative modelling and simulation have been used for a long period. The advancement in OM requires greater use of qualitative methods as the use of quantitative methods display many weaknesses. Due to the complex and multivariate nature of issues investigated, the validity of assumptions upon which the design and findings are based is questionable. Since the phenomenon is studied in isolation of its context, this raises questions about the assumed causal relationships among variables (Kiridena and Fitzgerald, 2006). In order to reduce the gap between theory and practice and increase the practical implications of OM research, contemporary research in OM has shifted towards the use of empirical research to supplement mathematics, modelling and simulation to develop and test theories (Forza, 2002). The most frequently used qualitative methods in the OM field are surveys and case studies (Taylor and Taylor, 2009).

Compared to the early 1980s, contemporary studies have shown a remarkable increase in the quantity and quality of survey research in the OM field (Rungtusanatham et al., 2003). Survey research has contributed greatly to the advancement of operations and supply chain management (OSCM) as it has provided evidence for validation and adjustment to theories (Boyer and Swink, 2008; Craighead et al., 2011). In many cases in OSCM research, the measured variables are a function of behaviour or organisational norms which cannot be measured objectively.

Survey research provides a low cost mean for measuring factors or attributes of an operational or supply chain nature which cannot be directly observed. It can deal with perceptual measures when objective measures might be unfeasible to obtain (Boyer and Swink, 2008). Survey research methods are widely used in analytical studies, particularly evaluation studies and case–control studies. Both studies are designed to examine possible cause–effect relationships. However, evaluation studies start from the cause (intervention) and investigate possible effects, whereas case–control studies start from the effect and investigate possible causes (Kalton and Piesse, 2007).

The case study method has been widely used in qualitative research and has made a significant contribution in the OM field compared to other qualitative methods (Barratt et al., 2011). Despite challenges inherent in the case study research method, such as being time consuming, requiring skilled interviewers and applicability of findings, case research can have very high impact in the OM field, particularly in the development of new theory. The use of a case study has been one of the most powerful research methods considered in developing concepts and theories in OM, from lean production to manufacturing strategy. In contrast to other areas of management research, OM addresses both the physical and human elements of the organisation, where case research can be used in developing new theory and ideas and in theory testing and refinement (Voss et al., 2002). Using qualitative case studies in the OM field contributed to theory building in new areas and integrating existing theory with new contexts. Qualitative case studies are appropriate when exploring an area not previously studied. This is why manufacturing strategies are main OM area using the qualitative case study method. Conducting deductive qualitative cases in the OM field has been limited. Most of the qualitative cases studies that have been conducted in the OM field adopted the inductive approach through describing a phenomenon, using theoretical sampling of multiple cases, and analysing data within and across cases for comparison purposes (Barratt et al., 2011).

Action research (AR) has also been introduced by many researchers as a valid qualitative methodology for research in OM. AR focuses on research in action, rather than research about action through studying social issues together with those who experience these issues directly. Accordingly, AR is participative research approach where members of the system being studied participate actively in the study (Gummesson, 2000; Coughlan and Coghlan, 2002).

Coughlan and Coghlan (2002) defined and explored the legitimacy of applying AR approach to the description and understanding of issues in OM. The study proved that an action-oriented research approach can be relevant and valid for the discipline of OM in order to address the operational realities experienced by practising managers while simultaneously contribute to knowledge. Action research case studies have been suggested as a suitable research approach to investigate OM real-world problems particularly in the logistics field (Na¨slund, 2002). Kumar et al. (2010) developed AR case study methodology to implement process improvement initiatives in three small and medium-sized food enterprises. The use of a multiple case study design in this study along with the positive results from all three case companies indicated the validity of action research case methodology as a powerful alternative methodology in OM field.

Boyer and Swink (2008, p. 344) argued that *"blind men use all their senses to compensate for the lack of vision. Why should we as researchers disparage any avenue of inquiry that will help describe the elephant?"* Much like the blind men and the elephant, using multiple approaches can provide a holistic understanding of OSCM phenomena. Although modelling and purely analytical techniques have seen advances in OSCM research, it should be noted that OSCM as a social science requires more than just a problem solving research. Empirical research methods (survey, case and experiments) are essential to cover social and behavioural elements involved in the OSCM area. Systems and decisions affecting business processes can be modelled while empirical studies of business processes are needed for the development and validation of models (Boyer and Swink, 2008).

Based on the above discussion, the study proposition to be investigated is "Utilising the relationship between a company's SC operations performance and its financial performance can allow the company to develop a procedure to identify and implement SCM practices by which financial performance can improve." This research proposition focuses on the relationship between SCM practices and financial performance improvements which was discussed in the literature review chapter. The study proposition is derived from previous studies in the area of SCM which confirmed the positive effects of SCM on an organisation's performance (see section 2.5).

To test this theoretical proposition, the study will follow a deductive research approach whereby both the quantitative and qualitative research methodologies are incorporated. This research is searching for the critical link between SC operations' performance, the company's financial performance and the consequences of this link. Through data analysis, the study can reject or confirm the critical relationship, derived from previous theories and research, between SC operations' performance and the company's financial performance. Thus, the appropriate loop according to Sagasti and Mitroff (1973) model would be "II, III, IV and I".

A quantitative research methodology will be conducted to create the framework of this study, while the empirical validation of the research framework requires both quantitative and qualitative research methodologies.

To develop the research framework, SCOR model will be used for mapping SC processes and identifying the corresponding performance measures for the mapped processes, then FAHP approach will be conducted to determine the relative importance weights of SC performance measures. Du Pont ratio analysis will be applied for evaluating a company's overall financial performance and identifying financial performance factors that need improvement, while DS/AHP model will be employed to link SC operations' performance to the priorities of financial performance factors.

A single quantitative case study will be conducted for the implementation of the research framework, while the explanation of the quantitative findings and the empirical validation of research proposition based on those findings need qualitative understanding. Focusing on a single manufacturing case provides more opportunities for in-depth observation which can help to understand the research phenomenon in a real life context and to challenge existing theory through real life situations and issues.

The next section reviews case study research method in more detail through providing an insight on the design and implementation of case study research method.

3.4 Case study research method

Yin (2003) identified three factors to determine the most appropriate research method to employ: firstly the types of questions to be answered, secondly, the extent of control over behavioural events and finally, whether the focus of these events is contemporary or historical. As illustrated in table 3.4, a case study research method is appropriate when: A "how" or "why" question is being asked about a contemporary set of events over which the investigator has little or no control.

Table 3.5: Relevant situations for different research strategies

Strategy	Form of research questions	Requires control of behavioural events?	Focuses on contemporary events?
Experiment	how, why?	Yes	Yes
Survey	who, what, where, how many, how much?	No	Yes
Archival records	who, what, where, how many, how much?	No	Yes/No
History	how, why?	No	No
Case study	how, why?	No	Yes

(Source: Yin, 2003, p.5)

According to Yin (1994, p.13) "*A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.*"

Easton (2010, p.119) defined a case study as "*a research method that involves investigating one or a small number of social entities or situations about which data are collected using multiple sources of data and developing a holistic description through an iterative research process.*"

Although there are many definitions of case study, they all have some common elements. The case study research approach provides a holistic view of the investigated phenomenon as it allows simultaneously to see the whole and the parts or to move the parts around to create different combinations (Chaiklin, 2000). Whether it applies to an individual, group, family, organisation or community, the case study contributes to the understanding of a complex real-life particular problem or situation in great-depth as well as the context in which this problem or situation occurs (Stake, 2000; Noor, 2008; Cooper and Morgan, 2008). An important strength of a case study is the ability to investigate the phenomenon in its context without the need to replicate it in a laboratory or experimental setting (Rowley, 2002). The holistic view of the investigated phenomenon in its real world settings enables researchers to develop grounded theories that are both practical and relevant. In addition, inferences on causal relationships can be made with more validity due to the longer term observations available (Bamford, 2008).

As stated earlier, the research will conduct quantitative empirical case study to test the validity of the research theoretical proposition, with respect to real-life operational situations whereby both quantitative and qualitative data collection methods will be employed.

According to Flyvbjerg (2006), empirical social science research is problem driven and not methodology driven which requires employing a combination of qualitative and quantitative methods to best help study the investigated research phenomenon. Relying on both qualitative and quantitative data collection methods enables the integration of data and knowledge from various sources which helps increase the transparency, reliability and objectivity of a case study in a way that allows other research to apply the case procedures and end up with the same or similar conclusions (Scholz and Tietie, 2002).

Case study research method has been explored in depth by three authors in particular, Yin (1994), Stake (1995) and Merriam (1998) (Myers, 2007; Brown, 2008).

Yin (1994) focused on principles and designs of case study research. He provided an insight on the design and implementation of case study research method based on four stages: case design, data collection, analysis of case study evidence and writing the case study report. Since the case study conducted in this research will be based on the methodology introduced by Yin (1994) and its updates (Yin, 2003; 2009), a detailed discussion of Yin's (1994) methodological approach to design and implement a case study will be illustrated later in this section.

Stake (1995) is considered the most representative of the qualitative case study (Brown, 2008). He (1995, p. xi) defined a case study as "*The study of the particularity and complexity of a single case, coming to understand its activity within important circumstances*." Stake (1995) also emphasised interpretation as the most distinctive characteristic of qualitative inquiry. He stated that "*The function of the qualitative researcher during data gathering is clearly to maintain vigorous interpretation*" (p. 9).

Stake (1995) described three types of case studies to serve different research purposes: intrinsic, instrumental and collective case studies. In intrinsic case study research, the researcher needs to learn about a particular given case not to gain general understanding of some general problems. Instrumental case study research serves to understand or shed light on something else. In this type, the researcher needs general understanding of a research question and feels that he might get insight into the question by studying this particular case. In collective case study, the researcher choses more than one case to be coordinated in order to achieve some kind of representation.

Merriam (1998) mainly addressed the case study applications in education through adopting a qualitative practical approach. Similar to Stake, Merriam (1998, p. xiii) defined the case study as "*An intensive, holistic description and analysis of a bounded phenomenon such as a program, an institution, a person, a process or a social unit.*" She categorised qualitative case studies to serve educational purposes as particularistic, heuristic or descriptive. A particularistic case study focuses specifically on particular events, simulations or program. A heuristic case study allows the reader to understand the case whether through extending his experience, discovering new meanings or confirming what is known. A descriptive case study provides a detailed description of the phenomenon being studied based on information collected from a wide variety of sources and viewpoints.

In summary, Stake (1995) and Merriam (1998) had qualitative views of case study research method. Stake (1995) focused on "qualitative interpretation" of a case study phenomenon through integrating the researcher's observations and experience, while Merriam (1998) focused on "case study applications in education" from a qualitative perspective. On the other hand, Yin (1994) provided "a methodological approach" focusing on principles and designs of case study research (Myers, 2007; Brown, 2008). Accordingly, Stake's (1995) and Merriam's (1998) case study research focus best reflects the assumptions and frameworks associated with qualitative studies. Because of its quantitative, logical and methodological nature, Yin's (1994) case study research method is more appropriate to reflect the proposition and the framework associated with this study.

As mentioned above, Yin (1994; 2003; 2009) introduced four stages for doing a case study research namely; case design, data collection, analysis of case study evidence and writing the case study report. The procedures of conducting these four stages are illustrated in detail in this section.

3.4.1 Case design

Research design is the stage by which the researcher can draw the conclusion to the initial research questions from the collected data (Rowley, 2002). At this stage, the basic components of the investigation are identified, validity and reliability tests are established to ensure the quality of the research design, and finally a case study design is selected.

Yin (2009) listed five components of research design: the study's questions, the study's propositions, the study's units of analysis, the logic linking the data to the propositions and the criteria for interpreting findings. As mentioned before, in case study research, the research questions are most likely to be "how" and "why" questions. The study's propositions are derived from the research questions. However not all cases need to have propositions.

There are three types of case studies: exploratory, explanatory and descriptive case studies. The exploratory case study aims at setting the research question precisely. Thus, in the exploratory case study, rather than having propositions, data may be collected before formulating the research question. Descriptive and explanatory studies need propositions. The explanatory case is appropriate for causal studies when there is a need to explain set of events and how they relate to each other. In the descriptive case, the researcher tries to describe different characteristics of a phenomenon. Contrary to the exploratory cases, the explanatory and the descriptive cases require the research questions to be defined and translated into propositions prior to data collection. Then the data can be collected and analysed to support or refuse the research propositions (Yin, 1994, pp. 4-6).

Selecting the unit of analysis, or the case, is a critical step in designing case study research. The unit of analysis could be an individual person, a group, an event, an organisation or a country. Selecting the unit of analysis is mainly based on the research purpose, questions, propositions and theoretical context. However other issues could affect case selection, such as accessibility, availability of resources and time constraints.

Case studies can be classified into holistic or embedded studies according to the number of units of analysis. Each of these two categories can be applied either for single or multiple-case studies. Holistic case studies examine the case as one unit. Although this approach provides an overall picture of the case, this picture might be superficial and doesn't reflect the changes in the unit of analysis that could impact the original research design. In embedded cases, the unit of analysis is broken into subunits, each of which is studied individually. Then results are gathered from these sub units to draw an overall conclusion. The most challenging issue in conducting an embedded case is to achieve an overall picture of the case from the analysis of the sub-units. Finally, after selecting the unit of analysis, the remaining aspects of research design components are to determine the appropriate data to support or reject the propositions and to reflect on the criteria for interpreting the findings (Rowley, 2002).

Table 3.6 illustrates different case study designs according to the two main categories of designs (holistic or embedded) and along two dimensions (single or multiple) in order to identify the number of units of analysis and the number of case studies involved in each design.

Table 3.6: Case study designs

	Single case designs	**Multiple-case designs**
Holistic (single unit of analysis)	Type 1	Type 3
Embedded (multiple units of analysis)	Type 2	Type 4

(Source: Rowley, 2002)

To judge the quality of a case design, four tests should be conducted: construct validity, internal validity, external validity and reliability. Construct validity establishes appropriate operational measures for the concepts being studied. Enhancing construct validity can reduce the subjectivity of a case study by linking data collection process to research questions and propositions. Internal validity is applicable only for explanatory studies and not for descriptive or exploratory studies as it refers to demonstrating a causal relationship in which certain conditions lead to other conditions. External validity tests the extrapolation of generalisable research findings beyond the immediate case. It establishes the domain to which a study's findings can be generalised analytically, not statistically. In analytic generalisation, previously developed theory is compared to the empirical results of single or multiple case studies whereby findings of a particular case are generalised to a broader theory. Reliability demonstrates that the same operations and procedures of conducting a case study can be repeated by other researchers and achieve similar findings. In real life, it is difficult to achieve the similar findings even if researchers followed the same procedures of conducting a case study as data and people might be different from one event to another. However, having differences can enrich the investigation by providing additional sources of information (Riege, 2003).

Table 3.7 recommends many approaches for ensuring validity and reliability of a case study design. External validity can be achieved through the analytical generalisation of findings while several data collections and analysis tactics can be employed to ensure construct validity, internal validity and reliability. These tactics are discussed below in the data collection and analysis sections.

Table 3.7: Case study tactics for four designs tests

Tests	Case study tactics	Phase of research in which tactic occurs
Construct validity	• use multiple sources of evidence • establish chain of evidence • have key informants review draft case study report	Data collection Data collection Composition
Internal validity	• do pattern-matching • do explanation-building • address rival explanations • use logic models	Data analysis Data analysis Data analysis Data analysis
External validity	• use theory in single-case studies • use replication logic in multiple-case studies	Research design Research design
Reliability	• use case study protocol • develop case study database	Data collection Data collection

(Source: Yin, 1994)

3.4.2 Data collection

Yin (2003) demonstrated three key principles to be considered during the phase of data collection in order to improve the quality of a case study design: triangulation, case study database and chain of evidence. Triangulation refers to using evidence from different sources to reach the same findings. It is one of the tools that can be used to assure the construct validity of a case study research design. According to this principle, multiple data sources can be used based on both quantitative and qualitative approaches. The appropriate sources should be identified with respect to the problem and research questions being addressed (Cooper and Morgan, 2008).

A well organised data base of the evidence collected is needed to facilitate the repeatability of the research and increase the reliability of the information in a case study. Maintaining a chain of evidence is another principle to be followed to increase the construct validity of case study design. It refers to the ability to follow the derivation of any evidence from initial research questions to conclusions. According to this principle, different sources should be accessible in the database and supported by the appropriate citation (Yin, 2003).

Yin (2009) identified the most commonly used sources including: documentation, archival records, interviews, direct observations, participant-observation and physical artifacts. Each of these different sources has different approaches to deal with and provides a different view of the case. Table 3.8 provides a brief insight on these sources and their strengths and weaknesses.

Table 3.8: Sources of evidence

Source of Evidence	Description	Strengths	Weaknesses
Documentation	• Relevant to every case study topic • can take many forms such as: letters, e-mails, memoranda, written reports of events, formal studies, administrative documents, mass media documents, websites etc.	• corroborates and augments evidence from other sources • can be reviewed repeatedly • unobtrusive - exist prior to case study • contains exact information-names, references, titles etc. • has broad coverage- long span of time	• difficult retrievability • biased selectivity • reporting bias - reflects author bias • access - may be blocked

Archival Records	• often taking form of computer files and records • they could be: service records, organisational records, maps and charts, lists of names , survey data, personal records (diaries- calendars-telephone listings)	• same as above for documentation • precise and quantitative	• same as above for documentation • difficult accessibility due to privacy reasons
Interviews	• essential sources of case study information • usually they take one of three main types: 1- Unstructured interview (open-ended nature): to ask the interviewee to express his opinion without following a certain set of questions. 2- Semi structured interview (focused interview): respondent interviewed for a short period of time and it takes conversational manner, but follows certain set of questions derived from a case study protocol. 3- Structured interview (survey): entails more structured questions.	• targeted - focuses on case study topic • insightful - provides perceived causal inferences	• bias due to poorly constructed questions • inaccurate due to response bias, poor recall, and poor or inaccurate articulation • reflexivity - interviewee gives what interviewer wants to hear
Direct Observation	• making field visit to the site to observe behaviours or environmental conditions • it can range from formal to casual data collection activities	• reality - covers events in real time • contextual - covers event context	• time and cost consuming • selectivity - might miss events unless broad coverage • reflexivity – event may proceed differently because it is being observed
Participant Observation	• special type of observation in which observer may participate in the events being studied	• Same as above for direct observations • insightful into interpersonal behaviour	• Same as above for direct observations • bias due to investigator's manipulation of events
Physical Artifacts	• physical evidence such as: technological device, tool or instrument, work of art etc. • may be collected or observed as part of field visit	• insightful into cultural features and technical operations	• selectivity • availability

(Adopted from: Yin, 2009)

Because of this diversity of sources, having a case study protocol is essential to guide data collection procedures in a multiple-case study, and is desirable in a single-case study. A case study protocol should include: an overview of the case study project, field procedures, case study questions and a guide for the case study report. It presents a major tactic to ensure the reliability of the case study research as it helps to indicate types of evidence that might be relevant. It could specify types of people to be interviewed, documents to be analysed or any other data collection operational terms in order to ensure that the same procedures are carried out from one case to another (Yin, 1994).

Once the evidence from different sources has been collected and reviewed, the final step in data collection phase is to validate the data collection process by having informants. Having key informants is considered one of the approaches that can be used to achieve the construct validity of a case study research design. Although the informants may disagree with the researcher interpretations of the case; they should ensure the unbiasedness in presenting the basic facts (Yin, 2003). The sources and the steps of data collection for this research will be indicated later in chapter four and chapter five.

3.4.3 Data analysis

Case study analysis is not an easy task to accomplish as there are no specific procedures to be followed during such phase. In order to reduce the difficulties of the analysis procedures, Yin (2003) presented three general analytic strategies, namely: relying on theoretical propositions, thinking about rival explanations and developing a case description. The first strategy is to follow the theoretical propositions which reflect research questions, reviews of literature and new hypotheses or propositions. Based on such propositions the original objectives, case design and data collection plan are formulated. The second strategy tries to define and test rival explanations of the case and is especially appropriate in doing case study evaluations. The third strategy aims to organise the case study through developing a descriptive framework. Compared to the other two strategies, this strategy is not preferable. However, it could serve as an alternative if there is a difficulty to implement the other two strategies. Also it is relevant to descriptive studies and may help in situations when identification of causal links needs to be analysed.

Along with any of these strategies, analytic techniques were recommended by Yin (2009) to be used as tools in order to deal with the problems of internal validity and external validity in doing case studies. These techniques are discussed below:

- Pattern Matching- it refers to comparing an empirical pattern with a predicted one. Using this technique increases internal validity if the patterns coincide.
- Explanation building- it presents a special type of pattern matching for independent variables. It concerns analysing the degree to which the observed pattern matches the predicted one.
- Time-series analysis- it lays the conclusion of the case study. According to the nature of the case, the time-series technique used could be: simple time-series including a single dependent or independent variable, complex time-series including a multiple set of variables or chronologies to cover descriptive and analytical purposes. Regardless of the type of time-series, it should observe the time trends and examine relevant “how?” and “why?” questions about the relationship of events over time.
- Logic model- it stipulates a complex chain of events over time staged in cause-effect patterns. It can be considered as another form of pattern matching as it matches empirically observed events to theoretically predicted events. A logic model could be: individual level logic model (individual person), firm or organisational-level logic model,

alternative configuration for an organisational-level logic model or program-level logic model. Selecting the appropriate type of logic model is subject to the unit of analysis and situation to be examined. According to this technique, firstly the logic model is identified, then data is collected in order to test the model through determining the extent to which the collected data supports it.

- Cross-case synthesis- compared to the previous four techniques, which can be used either with single or multiple cases, the cross-case synthesis technique can be used only with multiple cases (at least 2). According to this technique, each case study is treated as a separate study, and then findings are aggregated across this series of individual studies.

In addition to these analytic strategies and techniques, during the analysis phase, researchers should take into consideration several issues in order to produce a high quality analysis. The analysis should utilise all the relevant evidence, demonstrate all major rival interpretations and address the most significant aspect of the case study. Also, the researchers' prior expert knowledge in the area of the case study should be objectively employed to draw an accurate analysis (Tellis, 1997).

3.4.4 Writing the case study report

The main issue that should be considered when writing the case study report is to decide what is to be included in the report and what is to be left out. There is no stereotypic form for writing a case study report, but three steps should be executed: identifying the audience for the report, setting the compositional structure and following certain procedures. Since different audiences have different needs and interests, the report's structure and contents will vary according to these (Yin, 1994).

3.5 The research methods, models and techniques

The research methods, models and techniques used in this research (the SCOR model, the FAHP technique, Du Pont ratio analysis and DS/AHP model) and the rationale of combining them to create the framework are explained in this section.

3.5.1 The SCOR model

As reviewed in chapter two, several process-based SC measurement systems have been developed (see section 2.3.1) but the SCOR and GSCF models are the two most widely applied frameworks in the literature. Although these systems suggest the implementation of standard cross-functional business processes only the GSCF and SCOR frameworks include business processes that could be used by management to achieve cross-functional integration (Lambert et al., 2005).

In this research, SCOR model framework will be employed, since the research framework focuses on integrating and managing SC processes within manufacturing companies. As illustrated in section 2.4.2, the narrow focus of the SCOR makes it an appropriate framework to achieve cross functional business processes integration within the organisation structure, while the wide scope of the GSCF framework makes it more adapted for achieving external SCM integration across the SC.

According to Stewart (1997), the SCOR model represents the first cross-industry framework for integrated supply chain management as it provides standard descriptions of supply chain processes that make up the SC and a framework for defining relationships among these standard processes. As discussed earlier in literature, several studies have been developed utilising the SCOR model to measure SC performance (Bullingery et al., 2002; Theeranuphattana and Tang, 2008; Hwang et al., 2008; Camerinelli, 2009; Kremers, 2010; Bai et al., 2012; Agami et al., 2012; Kocaoˇglu et al., 2013) (see chapter 2). The SCOR model is based on five core processes – plan, source, make, deliver and return – altogether called level 1 processes. The "plan process" balances the demand and supply to best meet the sourcing, manufacturing and delivery requirements. The "source process" is the process of purchasing goods and services to meet planned or actual demand. The "make process" includes production of finished goods or performing of services to meet planned or actual demand. The "deliver process" includes delivering of finished goods and services to meet planned or actual demand. Finally the "return process" is the receiving of returned products for any reason (Supply-Chain Council, 2008). The general structure of applying the SCOR model is illustrated in Appendix 5.

As previously mentioned, the SCOR model has limited scope as it focuses only on engaging partners from the logistics, production and purchasing functions of the supply chain in its five supply chain management processes (plan, source, make, deliver and return) (see table 2.2). However, the relatively narrow focus of SCOR makes it easier to implement, since the activities of logistics, production and purchasing are already naturally integrated within an organisational structure (Lambert et al., 2005).

Using this model allows companies to select the appropriate performance measures as it includes ten standard performance metrics to measure the performance of SC processes (perfect order fulfilment, order fulfilment cycle time, upside supply chain flexibility, upside supply chain adaptability, downside supply chain adaptability, supply chain management cost, cost of goods sold, cash to cash cycle time, return on supply chain fixed assets; and return on working capital) which fall into five standard performance categories: reliability, responsiveness, flexibility, cost and asset metrics. These ten performance metrics are designed to provide a view of overall SC performance at level 1 (top level) while the SCOR model levels 2 and 3 (configuration level and process element level) supporting metrics are keys to the level 1 metrics (Hwang et al., 2008).

Table 3.9 defines five standard performance categories for a SC and links these performance categories to SCOR model level 1 metrics. An example of the implementation of SCOR model standard performance metrics to measure the performance of a company's entire SC processes is presented in Appendix 6 (see figure A6.1).

Table 3.9: Performance attributes and associated level 1 metrics

Performance attribute	Performance attribute definition	Level 1 metric
Supply Chain Reliability	The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.	Perfect Order Fulfilment
Supply Chain Responsiveness	The speed at which a supply chain provides products to the customer.	Order Fulfilment Cycle Time
Supply Chain Flexibility (Agility)	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.	Upside Supply Chain Flexibility
		Upside Supply Chain Adaptability
		Downside Supply Chain Adaptability
Supply Chain Costs	The costs associated with operating the supply chain.	Supply Chain Management Cost
		Cost of Goods Sold
Supply Chain Asset Management	The effectiveness of an organisation in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Cash-to-Cash Cycle Time
		Return on Supply Chain Fixed Assets
		Return on Working Capital

(Source: adapted from SCOR Model - Version 9, Supply Chain Council, 2008)

3.5.2 <u>The FAHP technique</u>

One of the most critical challenges facing decision makers in different industries and businesses is to determine the relative importance of the evaluation criteria with respect to the overall objective. The natural limitations of human capability to compare or to decide on more than two factors or alternatives makes the multi-criteria decision-making process (MCDM) complex and challenging (Deng, 1999; Abdul Moneim, 2008). Numerous MCDM analysis methods have been proposed (such as SAW analysis model, TOPSIS method and VIKOR method) in order to deal with decision or selection problems (Matsatsinis and Samaras, 2001; Kuo et al., 2006). One of the most widely used approaches for MCDM is the analytic hierarchy process (AHP) method (Mikhailov, 2003).

In the AHP, the decision problem is structured in a hierarchy of different levels of elements and then a pair-wise comparison matrix is used to determine the relative priorities of the decision elements (weights of the criteria). The pair-wise comparisons are accepted as linguistic evaluations or assessments expressing the relative importance of pairs. Finally, the weights of each element in each hierarchical level are aggregated to the next level by applying the principle of hierarchic composition (Mikhailov, 2004).

As illustrated earlier in literature review, the AHP method was the most commonly applied MCDM approach in the area of prioritisation and choice of SC metrics and measures (see section 2.3.3). However, in most real life cases, the data and information available are incomplete and the decision environment is uncertain and complex. In these cases, the classical AHP technique is not valid and decision makers could be uncertain about their level of preferences (Kahraman et al, 2003). In recent years, several studies have been developed to handle this kind of uncertainty in preferences using fuzzy set theory and the application of fuzzy set theory to multiple criteria evaluation methods (Kuo et al., 2006; Leung and Cao, 2000). Fuzzy set theory is a tool which can deal with this type of inexact data by assigning to each object a grade of membership ranging between zero and one (Kahraman et al, 2003). Since it is more accurate to give interval judgements than fixed value judgements, a fuzzy extension of AHP was developed to reflect the uncertainty in real life (Lee et al., 1999).

In the FAHP procedure, the pair-wise comparisons in the judgement matrix are fuzzy numbers that are modified by the designer's emphasis. Preference weights among main-attributes, sub-attributes and indicators are obtained by using a questionnaire survey. The survey respondents are asked to rank the components of a given layer by giving interval judgements rather than fixed value judgements according to its comparative importance. Afterwards, the elements of a given pair-wise comparison matrix are generated to examine the relative significance of any two components in the proposed hierarchy layers. Correspondingly, the associated component utilises FAHP (Kunadhamraks and Hanaoka, 2008).

The application of fuzzy logic in the area of SC performance measurement has been studied by many researchers. Several methods have been proposed utilising fuzzy logic to measure SC performance. Chan and Qi (2002) proposed an innovative channel-spanning performance measurement method from a systems perspective using fuzzy set theory to support comprehensive measurement of the holistic performances of supply chains.

Chan et al. (2003) developed a mathematical model employing fuzzy set theory to measure the integrated performance of complex SCs. First, the appropriate qualitative and quantitative measures were selected and their importance weights were determined based on a geometric scale of triangular fuzzy number. A fuzzy performance grade was defined for each measure and consequently a performance score was assigned for each measure. Finally, the performance scores of all measures were consolidated to calculate the performance index which indicated the performance of the SC under evaluation.

Chan and Qi (2003a) introduced a cross-organisational performance measurement method from a systematic perspective to measure the holistic performance of complex supply chains. Fuzzy set theory was utilised to address the real situation in judgment and evaluation processes. A process-based model was developed based on fuzzy measurement algorithm to judge and evaluate the performance of SC processes in order to support performance improvement in SCM.

Alex (2007) introduced a new approach to model the uncertainties involved in supply chain management using the fuzzy point estimation. This approach presented a basic description and analysis for SC systems mathematically to obtain the optimal solution through classifying the complex situations into simple chains mainly: linear chain, anti-tree to describe a centralised SC and multiple anti-trees to describe a decentralised chain.

Xu et al. (2007) developed a framework identifying the most important attributes to measure SC performance using AHP and fuzzy logic. The framework identified five attributes to characterise a supply chain (reliability, responsiveness, flexibility, re-configurability and cost). For different SC strategy (Lean SC, Agile SC, Leagile SC or Adaptive SC), the weights of these attributes would be different. AHP approach was used to determine the weights of different attributes with respect to SC strategies. Fuzzy logic technique was applied to integrate both qualitative and quantitative metrics to provide a complete view of the supply chain performance.

Yeh et al. (2007) proposed a modified 2-tuple fuzzy linguistic computing model based on the framework of the Six Sigma DMAIC process in order to evaluate the performance of SCM. A delphi method was used to secure expert opinion on criterion selection, weighting identification and performance appraisal expressed by fuzzy linguistic variables.

Kamalabadi et al. (2008) presented a new approach for competitiveness measurement of SCM using a Fuzzy Multi Attribute Decision Making method. According to this approach, the best criteria for appraising supply chain performance in terms of increasing competitiveness were selected based-on balanced scorecard model, then the relative importance of chosen criteria were determined using fuzzy AHP technique. The process of SC performance measurement involved ambiguous qualitative data. These qualitative terms can be transformed into quantitative terms using fuzzy AHP technique.

Olugu and Wong (2009) suggested applying fuzzy logic operations in measuring the performance of a green or sustainable supply chain (close loop chain). The suitable performance metrics for this type of SC must include measures for the environmental categories as well as the traditional operational measures such as cost, delivery time, customer satisfaction, flexibility and quality. However, some of these measures are not easily presented in quantitative terms. Using fuzzy logic, qualitative measures were quantified and integrated with quantitative measures, both traditional and environmental, in order to establish the green positioning of a supply chain.

Zaman and Azharul (2011) proposed a model to evaluate SC performance and identify improvement areas for each criterion using triangular linguistic fuzzy numbers. The model considered all the SC performance criteria (input, output and flexibility), then converted the values to triangular linguistic fuzzy numbers in order to evaluate overall SC performance under different situations.

Ganga and Carpinetti (2011) developed a model to predict the performance of the SC using SCOR model and fuzzy logic. In order to predict the performance of SC processes, causal relations were established among the variables of SCOR model standard performance metrics based on fuzzy logic. This predictive model provided a feasible approach to predict SC performance in order to support the decision making process of managing performance of supply chains.

The previous discussion introduced the SCOR model as a SCM framework. Also the FAHP method was presented and its applications in SC performance measurement were reviewed. The discussion showed how each of these two different approaches (the SCOR model and the FAHP method) can be applied to measure SC performance. The next section illustrates the rationale for combining both approaches in order to propose a better alternative for measuring SC operations' performance.

3.5.3 Combining the SCOR model and the FAHP technique

Despite all the advantages that SCOR model and FAHP technique have, there are some issues regarding the successful implementation of these approaches in measuring SC operations' performance.

Although FAHP appears to be an appropriate tool for analysing complex multi-criteria decision-making problems, it does not specify relevant measures for measuring SC operations' performance. The inability to reach relevant performance measures and define SC metrics can represent a limitation for successful implementation of the approach. Using the SCOR performance metrics with the FAHP technique allows decision makers to deal with a limited number of critical measures to evaluate supply chain performance (Theeranuphattana and Tang, 2008).

However, there is a debate about how SCOR performance metrics can be used to derive a quantifiable supply chain performance measure. SC performance measures should be linked with strategies, which may need a quantitative tool to link SCOR metrics to SC strategies (Huang et al., 2004). According to Lambert et al. (2005), a supply chain management framework can be evaluated by how it is linked to the corporate strategy (the strategic driver) and the extent to which it helps the achievement of the strategic objectives. The scope of the SCOR model framework is not linked directly to the corporate strategy. SCOR processes are developed based on the operations strategy while the functional strategies and the corporate strategy are not explicitly considered in this model. By incorporating the AHP measurement methodology in the

SCOR model, managers can quantify – from their judgments – the weights of influence of SC strategy on individual performance measures (Huang et al., 2004).

As mentioned earlier, Theeranuphattana and Tang (2008) proposed a model combining the distinct advantages of Chan and Qi's (2003b) model with the pragmatism of the SCOR model as an alternative SC performance measurement approach that is more practical and efficient than using each model separately (see chapter 2). Following this, applying FAHP to the SCOR model can help to overcome some of the barriers of using each approach separately and hence offering a better alternative for measuring SC operations' performance. In addition, combining both approaches can also help managers to determine the degree to which performance metrics contribute towards the success of a particular strategy.

3.5.4 Du Pont ratio analysis

As discussed in chapter two, ratio analysis is considered one of the most important, reliable and widely used techniques for measuring and evaluating a company's financial performance. Du Pont ratio analysis is a financial ratio commonly used to measure an organisation's financial performance. The analysis of the Du Pont ratio evaluates the areas of profitability and operating efficiency through assessing the performance of the components contributing to return-on-assets (ROA), namely: revenue (sales), cost and total assets. ROA measures how much profit a company generates compared to the assets employed in the business. It consists of a profitability measure (Net Profit Margin) and an efficiency measure (Total Assets Turnover) which can be expressed in the following formula (Dehning and Stratopoulos, 2002):

Return on Assets = Net Profit Margin x Total Assets Turnover

$$= (Net\ Income / Sales) \times (Sales / Total\ Assets) \quad (1)$$

The Du Pont ratio can also be broken into more components depending upon the needs of the analysis (Nissim and Penman, 2001). DuPont analysis can also be applied based on the return on equity (ROE) ratio. It can be decomposed into the three multiplicative ratios of Profit Margin, Asset Turnover, and Equity multiplier as follows:

Return on Equity = Net Profit Margin x Total Assets Turnover x Equity multiplier

= (Net Income/Sales) x (Sales/Total Assets) x (Total Assets/Equity) (2)

The ROE form is not applicable for this research as ROE is affected by changes in the company's financial structure (Soliman, 2007). Since this research focuses on how the company performs business operations not on how it decides to finance such operations, the ROA form is more relevant.

3.5.5 DS/AHP model

To link SC operations' performance to the company's financial performance, the proposed method employs DS/AHP model developed by Beynon et al. (2000). According to the DS/AHP model, the importance weight of the evaluation criteria is determined with respect to the priorities of related decision elements. Using this model, the importance weights of SC operations' performance measures can be determined with respect to the priorities of the company's financial strategy. Consequently, SC operational strategy is formulated based on these priorities through linking SC operational strategy to the focus area of enhancing the financial performance.

DS/AHP model is a multi-criteria decision-making model that incorporates Dempster-Shafer theory (DST) with the philosophy behind the analytical hierarchy processes (AHP) technique to improve traditional approaches to multi-criteria decision modelling (Beynon et al., 2000; Beynon, 2005b).

DST is a generalisation of the Bayesian theory of subjective probability (Smarandache, 2003). The Bayesian theory quantifies judgements about a question by assigning probabilities to the possible answers to that question while DST provides a non-Bayesian way of using mathematical probability to quantify subjective judgements. It allows the derivation of degrees of belief for a question from probabilities for a related question and then considers the implications of these probabilities for the question of interest (Shafer, 2008).

The basic difference between probability theory and DST is that DST framework is a broader framework for representing uncertainty than probability. Under the probability framework, the sum of probabilities of all possible values of a variable equals one while in the DST, uncertainty is not only assigned to the single elements of the frame but also to all other proper subsets of the frame and to the entire frame (Srivastava, 1997; Bovee et al., 2003).

DST gives the ability to assign probability measures (basic probability assignments) to groups of objects rather than in classical probability theory where measures must be given to individual objects. The utilisation of DST in DS/AHP allows decision makers to make preference judgments on groups of decision alternatives (D.A.'s) rather than considering all D.A.'s (as in the classical AHP technique) and consequently, the number of comparisons can be reduced (Beynon, 2002) .

Incorporating DST allows the related measure of ignorance to be calculated on the judgements made by the decision makers. Within DS/AHP decision makers can ignore those D.A.'s that they do not have an opinion towards. They only need to give judgments to the D.A.'s that they have a level of opinion towards which enables the decision maker to have a greater level of control on their judgements compared to standard AHP methods (Beynon et al., 2001; Beynon, 2005a).

3.5.6 Rationale for the method developed to link SC operations' performance to a company's financial strategy

Connecting SC activities to the company's strategic financial objectives represents an opportunity for companies to gain competitive advantages by focusing on linking SC processes' performance to the focus area of enhancing the financial performance.

As the literature review revealed (see section 2.5), the concept of the link between SCM practices, financial performance improvement and the consequence applications of this link are still immature in the literature. Previous studies on supply chain-financial performance link did not achieve the critical link between supply chain performance and business performance. A common drawback of studies undertaken in this field is that they do not describe the methodology applied in detail, which makes the assessment of results rather difficult (Toyli et al., 2008). This consequently leads to the need for an applied methodology linking SCM practices to the company's strategic financial objectives.

A method derived from Presutti Jr. and Mawhinney (2007) is developed in this study to link SC operations' performance to a company's financial strategy. Presutti Jr. and Mawhinney (2007) introduced one of the first and most remarkable studies that demonstrated how supply chain performance can be linked to a company's financial performance. To explore the link between supply chain performance and the company's performance, Presutti Jr. and Mawhinney linked the SCOR model level 1 standard performance metrics (reliability, responsiveness, flexibility, cost, and assets) for measuring SC processes' performance to the Economic Value Added (EVA) components (revenue, cost, and assets) as a comprehensive measure of the company's profitability in relation to the amount of capital employed. According to this method, SCOR metrics performance attributes that have a direct impact on the customer (customer facing) were linked to the revenue component of EVA while SCOR metrics performance attributes that have a direct impact on the organisation (internal facing) were linked to the cost and assets components of EVA.

Although this method demonstrated how supply chain metrics can be linked to a company's financial metrics, it did not specify how this link can be utilised to enhance the company's overall financial performance. The method proposed by Presutti Jr. and Mawhinney assumed that EVA components (revenue, cost, and assets) have the same influence weighting on the company's financial performance. It is considered relevant to set the priorities of these components according to the company's financial strategy in order to highlight the components that need improvement with respect to the focus areas for enhancing the financial performance. Moreover, setting priorities for these components enables the development of SC operational strategy linked to the company's strategic financial objectives through identifying SC processes and measures that have a significant impact on the focus areas of the company's financial strategy.

In addition, EVA metrics measure the value created by the company through evaluating its profitability in relation to the amount of capital employed. Linking SC operations' performance to the financial performance requires financial performance metrics which analyse the company's financial performance in terms of operating efficiency as well as profitability.

Presutti Jr. and Mawhinney's method (2007) also addresses SCM as the only factor that can impact a company's financial performance. It does not address the impact of ignorance factors, out of the company's control, such as the political factors which may impact a company's financial performance and thus should be considered.

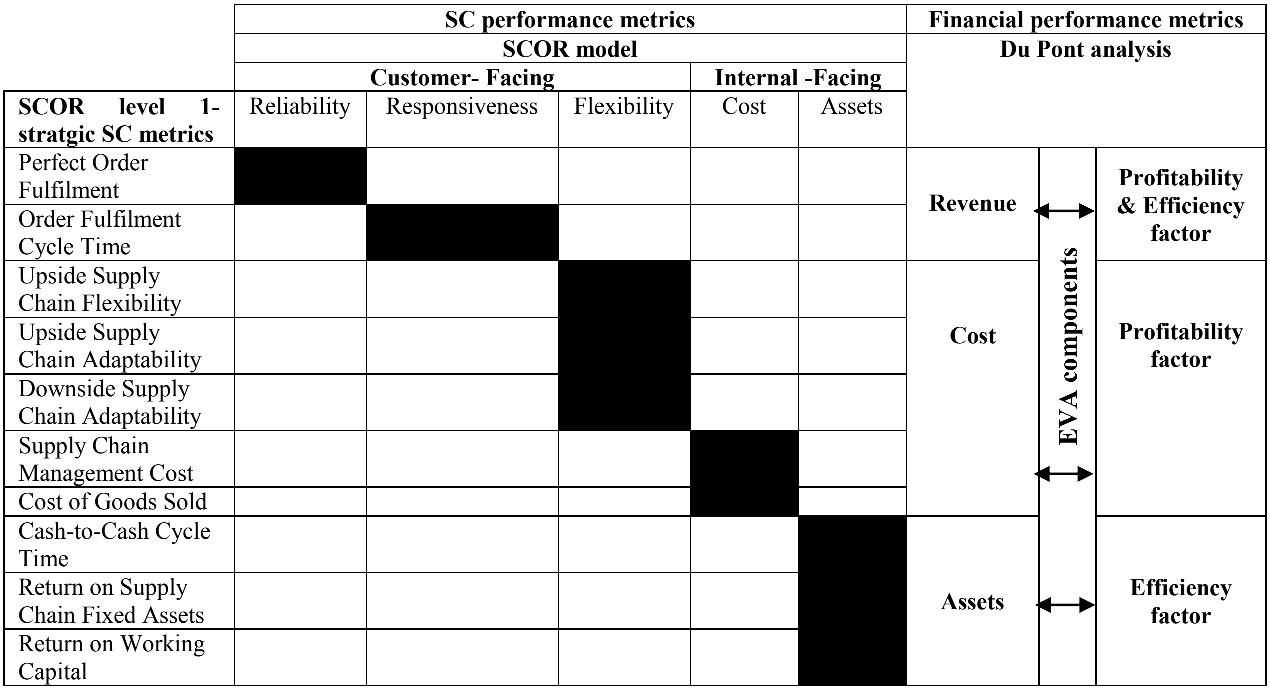
To overcome the above obstacles, this research develops a method to link SC operations' performance to the priorities of the company's financial performance in the short-term and evaluates its impact on maximising profit as the company's primary long-term financial goal. SC operations' performance is evaluated based on SCOR model standard performance metrics while financial performance is evaluated in terms of efficiency and profitability based on Du Pont ratio analysis. The results of Du Pont analysis allow the priorities of financial performance factors (efficiency and profitability) to be determined through evaluating the contribution of each factor and highlighting factors that need improvement in the short-term.

Then, the DS/AHP model is used to link SC operations' performance to the priorities of financial performance factors through determining the relative importance weights of the main supply chain performance measures with respect to these priorities. The developed method illustrates how this link can be utilised to connect SC operations' performance to the company's short-term strategic financial objectives in order to contribute to improvement in the company's overall financial performance through impacting on its profitability and efficiency. Consequently, SC operational strategy is formulated based on the priorities of financial performance factors for better alignment with the company's short-term strategic financial objectives.

In addition, the method developed takes into consideration factors outside the company's control that can impact on a company's financial performance as it allows the use of the DS/AHP model to calculate the influence weight of the ignorance factor on the decisions made by the company.

To test the extent to which SC operations' performance is linked to a company's short-term strategic financial objectives, a Supply Chain Financial Link Index (SCFLI) is developed. SCFLI takes into consideration the relative importance weights of the five main SC performance measures at the top level of the SCOR hierarchy with respect to the priorities of the company's short-term strategic financial objectives. It aggregates the weighted rates of the main SC performance measures to reflect SC operations' performance with respect to the priorities of the company's financial performance.

As presented in figure 3.4, Presutti Jr. and Mawhinney (2007) considered the EVA components to link SC performance metrics to the company's financial performance. This is developed further in this research by incorporating Du Pont analysis in the financial performance metrics to illustrate the impact of SC performance on financial performance through assessing the contribution of each financial performance component (revenue, cost, and assets) to the improvement of the company's profitability and operating efficiency.



(Source: the author: further developed from: Presutti Jr. and Mawhinney, 2007; SCOR Model - Version 9, Supply Chain Council, 2008; and, Elgazzar et al., 2012a)

Figure 3.4: Linking SCOR model performance metrics to the financial performance factors

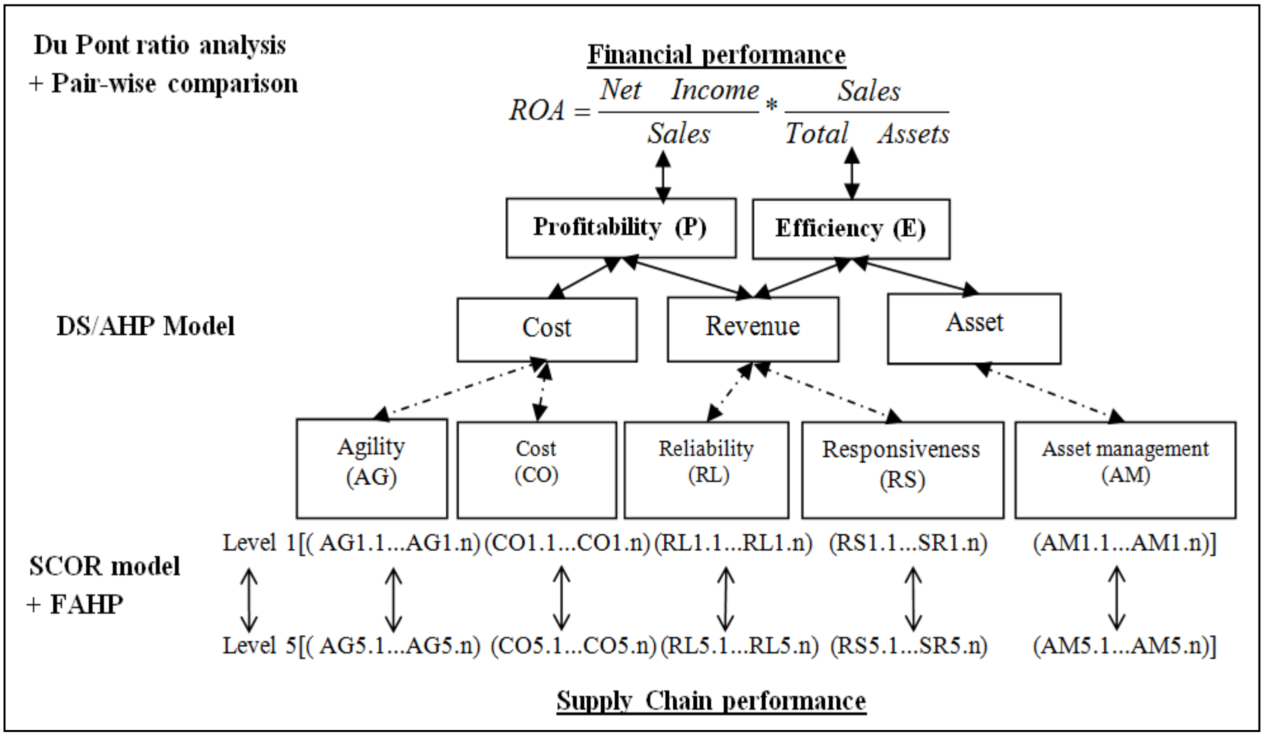
3.6 An overview of the research method

This study proposes a framework to align supply chain operational strategy and the company's overall strategy through linking supply chain operations' performance to the company's financial performance in the manufacturing sector.

A technique incorporating FAHP technique and SCOR model is developed to analyse, assess and improve the performance of SC operations. This technique allows organisations to assess and improve the effectiveness and the efficiency of SC operations in meeting SC goals and to contribute to overall improvement in the company's performance through identifying SC processes that are working well and areas where the SC might need improvement.

In addition, the framework introduces a method which links SC operations' performance to the company's short-term strategic financial objectives using the DS/AHP model. This method allows the determination of the impact of SC operations' performance on enhancing a company's overall financial performance through linking the performance of such operations' to the company's strategic financial goals. It enables companies to formulate SC operational strategies for optimising short-term strategic financial objectives through linking such strategies to the focus area of enhancing the financial performance.

The conceptual framework of the research method is summarised in figure 3.5 while a detailed explanation of the research method framework will be discussed in the next chapter using a numerical example. As illustrated, SC operations' performance is measured in terms of agility, cost, reliability, responsiveness, and asset management based on the SCOR FAHP technique. Financial performance is evaluated in terms of the company's profitability and operating efficiency based on Du Pont ratio analysis through assessing the performance of the components contributing to ROA (cost, revenue, and assets). Using Du Pont ratio analysis, the priorities of financial performance factors (profitability and efficiency) can be determined according to the assessment of their corresponding components. Then, SC performance metrics are linked to financial performance metrics using the DS/AHP model. This model allows the determination of the importance weights of the five main SC performance measures with respect to financial performance priorities. Consequently, SC operational strategy is formulated based on these priorities resulting in improvement in the overall financial performance.



(Source: the author, further developed from: Elgazzar et al., 2011a; and, Elgazzar et al., 2012a)

Figure 3.5: The conceptual framework of the research method

To demonstrate the applicability of the research method a case study of an Egyptian bottled water company will be conducted. Based on the literature that was reviewed in section 3.4, table 3.10 summarises the application procedures that will be used to conduct the current study at different research phases. While the phases of conducting the case study will be illustrated and discussed in detail in a later stage of this research.

Table 3.10: The application procedures of the current study

Research phase	Application procedures
Case design	**Case design:** Single holistic case study **Case type:** Explanatory **Unit of analysis:** an organisation **Case study tactics for four designs tests:** • Construct validity: use multiple sources of evidence, establish chain of evidence, and have key informants review draft of case study report • Internal validity: use a firm or organisational-level logic model • External validity: the analytical generalisation of findings • Reliability: use case study protocol, and develop case study database
Preparation for data collection	• Screening case study nomination • Protocol development and review

Data collection	**Data collection sources:** • Secondary sources: books, online references, periodicals, specialised journals, and SCOR model (version 8 and version 9) • Primary sources: Documentation, Archival records, Direct observation (formal, casual), Interview (open ended nature, focused interview, formal survey), and Informants **Data collection principles:** • Triangulation: use multiple data sources to reach the same findings • Create a case study data base: [Notes, documents, tabular material] • Maintain a chain of evidence: [Citation, data base collection circumstances (time/place), consistency with the protocol procedures]
Data analysis	**The analytic strategy:** Relying on theoretical propositions strategy **Analysis technique:** a firm or organisational-level logic model Immediate outcome (formulating the appropriate SC operational strategy) → intermediate outcome (SC performance) → ultimate outcome (financial performance)

3.7 Conclusion

A review of different research philosophies, approaches and strategies, particularly in the OM research area were presented in this chapter. It showed how research in the OM business field started to shift from tactical issues such as inventory management towards strategic issues such as SCM and performance measurement. The review has also shown the remarkable movement in OM research towards empirical methods particularly surveys and case studies.

The chapter presented the different research methods, models and techniques used to create the framework to align supply chain operational strategy and the company's overall strategy in the manufacturing sector. The framework would be created based on the model proposed by Theeranuphattana and Tang (2008) and the method introduced by Presutti Jr. and Mawhinney (2007) due to their appropriateness to the study's objectives in contrast with the other methodologies developed in the research area.

The research followed a deductive research approach whereby both the quantitative and qualitative research methodologies were incorporated and deductive qualitative case study would be conducted. A full picture of the case study research method was provided. The full process of conducting a case study has been discussed in detail starting from how to design a case study, followed by how to prepare, collect and analyse case study evidence, and finally how to write up a case report. In addition, a summary of the application procedures to conduct the current study at different research phases was presented, while a detailed discussion of these procedures will be presented later in separate chapters. The next chapter will present a detailed explanation of the creation of the research framework using a numerical example.

CHAPTER FOUR - RESEARCH FRAMEWORK

4.1 Introduction

In the previous chapter the research methodology and the general framework to align supply chain operational strategy and the company's overall financial strategy have been discussed theoretically. The SCOR FAHP technique was introduced to analyse, evaluate and improve the performance of SC operations. In addition, a performance measurement method was developed to link SC operations' performance to a company's financial strategy. SC performance metrics measure the performance of SC operations in terms of reliability, responsiveness, agility, cost and asset management based on SCOR model standard performance metrics and FAHP technique, while financial performance metrics evaluate and analyse the performance of the outputs of these operations in terms of efficiency and profitability using Du Pont ratio analysis.

Then, the DS/AHP model is employed to link SC performance metrics to the financial performance metrics. SCFLI was proposed to test the extent to which SC operations' performance is linked to the company's short-term strategic financial objectives. Analysing this index provides more control over the daily SC operations as it enables companies to trace SC processes that need improvement and consequently identify their related performance indicators for better SCM.

In this chapter, a detailed explanation of the research framework will be provided using a numerical example. The framework incorporates different methods, models and techniques whereby several details, stages and procedures are inherent. As mentioned earlier - following the model developed by Mitroff et al. (1974) - once the conceptual model is formulated the next step is to form the scientific model to be implemented (see figure 3.3). In this chapter, the scientific framework will be formed and clarified using a numerical example. Using a relatively simple numerical example will help to understand the framework before implementing it in a complex real life context. This numerical example will provide a holistic view of how the framework created can be implemented, making the implementation on the real case study much easier and more organised.

The remainder of this chapter is organised as follows. The frameworks for the proposed SCOR FAHP technique and the performance measurement method to link SC operations' performance to a company's financial strategy are illustrated in section 4.2 and section 4.3, respectively. In section 4.4, a numerical example demonstrating the research method is provided. Finally, conclusions are presented in section 4.5.

4.2 The framework for the SCOR FAHP technique

The proposed technique is developed through (Elgazzar et al., 2010):

(i) identifying the main processes and sub processes in the supply chain and mapping these processes to the SCOR model standard descriptions of SC processes,

(ii) identifying the corresponding performance measurement attributes for the previous mapped processes based on the standard performance metrics of SCOR model,

(iii) determining the relative importance weight of each attribute using fuzzy pair-wise comparison,

(iv) assigning a performance rate for each attribute using the performance rating scale,

(v) consequently, calculating the weighted rate for each attribute by multiplying the importance weight of each attribute by its performance rate

(vi) finally, aggregating the weighted rate for each attribute across all SC performance measurement attributes using the weighted average aggregation method to determine the performance index of the company's supply chain.

The procedures for the proposed technique are illustrated in the following steps.

1- Identifying the main processes and sub processes in the SC and mapping these processes to SCOR model's standard descriptions of SC processes

Recent times have witnessed attention towards the processes orientation within organisations instead of functional and product-oriented structure. The processes orientation promises both speed and organisational efficiency by focusing on value creation and viewing the organisation as linked chains of activities cutting across departments. Various applications have been adapted within organisations to establish processes orientation, however processes mapping is considered the most concrete application for processes orientation (Hellström and Eriksson, 2008). The process orientation can be adapted to most business environments using process mapping (Okrent and Vokurka, 2004).

According to CPS (2009), about 15 to 20 percentage of employees' working time can be wasted by re-doing things that are wrong, chasing things without result, querying incomplete instructions or doing other people's jobs. Applying processes mapping within an organisation allows a clearer understanding of business processes through defining the value added by each process in order to ensure the effectiveness and efficiency of a company's processes and to illustrate problems, waste and bottlenecks in order to determine areas of improvement.

Although processes mapping is an effective technique to enable organisations to graphically view their business system at any level of detail and complexity, the process descriptions rarely follow any standards. For that reason traditional process mapping tends to be resource-intensive and time-consuming due to the informal and ambiguous collection of process information (Wang et al., 2009).

According to the proposed SCOR FAHP technique, supply chain processes and sub processes are identified. A flowchart initially is drawn to represent SC processes by describing the sequence of tasks and decision points as they actually happen. Then, this initial flowchart is reviewed to ensure that the processes are correctly identified and linked. Finally, SC processes that have been identified and drawn in the flow chart are mapped to the SCOR model standard descriptions of supply chain processes.

As mentioned earlier, the SCOR model is organised around five primary management processes. Based on the combined knowledge of industry experts, major process workflows are standardised and include a basic control element. By describing supply chains according to these process building blocks, the model can be used to describe supply chains that are very simple or very complex using a common set of definitions. It can be customised to fit the specific supply chain of almost any organisation (Martin, 2009).

2- Identifying the corresponding performance measurement attributes for the previously mapped processes

The corresponding performance measurement attributes for the mapped processes are identified based on the standard performance metrics of the SCOR model. Consequently the hierarchical framework for supply chain performance measurement attributes can be established.

3- Prioritise the importance of the supply chain performance measurement attributes

To determine the relative importance weight of each SC performance measurement attribute, structured interviews are conducted with a group of decision makers comprising experts who have a good understanding of the day to day operations of the company's SC as well as an overview of the company's strategic vision and goals. Also, the selected experts should be from several managerial levels and belong to different organisational functions in order to have a wide range of judgements from different organisational levels and job roles perspectives. It is recommended that the group of decision makers comprise 3 to 5 experts, as it is difficult to get more than 5 experts that match the above mentioned criteria. However, if the group is smaller than three, it will not provide a meaningful judgement.

The selected experts are asked to assign a relative importance weight for a SC performance measurement attribute at different levels from the lowest implementation level to the configuration level. At this stage, an equal weight is assigned in the aggregation procedure (20%) to the main five measures at the top level (Reliability, Responsiveness, Flexibility, Cost and Asset management).

A fuzzy pair-wise questionnaire, based on triangular fuzzy numbers, is used to facilitate comparison of attributes. As presented in figure 4.1, the importance of the two measures related to each other is rated using a scale with the values 1, 3, 5, 7 and 9, where 1 denotes equally important, 3 for slightly more important, 5 for strongly more important, 7 for demonstrably more important and 9 for absolutely more important.

With respect to (……..)	Importance or preference of one main (sub) attribute over another									
Attribute	Absolutely more important **(9)**	Demonstrably more important **(7)**	strongly more important **(5)**	Slightly more Important **(3)**	Equally important **(1)**	Slightly more Important **(3)**	strongly more important **(5)**	Demonstrably more important **(7)**	Absolutely more important **(9)**	**Attribute**
C1										C2
………										……..
Cn-1										Cn

Figure 4.1: Questionnaire form to facilitate comparison of the importance of SC sub performance measurement attributes

For each expert response on the questionnaire, n-by-n reciprocal judgement matrixes are established. The pair-wise comparison matrix for the relative importance weights of the SC performance measurement attributes (W) can be expressed as follows:

$$A = [a_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{matrix} C_1 & C_2 & \dots & C_n \end{matrix} \\ \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{bmatrix} \end{array} \quad (1)$$

where $C_1, C_2, \dots, C_n$ denote the set of elements, $a_{ij} = 1$ and $a_{ij} =, \frac{1}{aij}$ i, j= 1, 2,…,n.

To aggregate the experts' responses, a fuzzy prioritisation method, derived from Chang et al. (2009), is adopted. Using this fuzzy prioritisation method, the experts' comparison judgements are represented as fuzzy triangular numbers where the uncertainty and imprecision of evaluations can be tackled.

A fuzzy pair-wise comparison matrix based on triangular fuzzy numbers is used in expressing the consolidated opinions of the experts. The triangular fuzzy numbers $\tilde{u}_{ij}$ are established as follows: (*L, M, U*) using the formulas from (2) to (6). Where *L* denotes the minimum numerical value, *U* denotes the maximum numerical value and *M* is the geometric mean which represents the consensus of most experts (see figure 4.2).

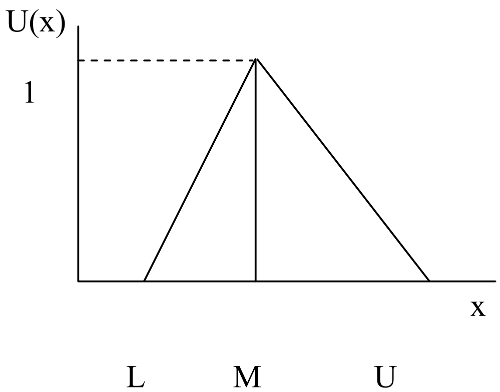


Figure 4.2: triangular fuzzy numbers

$$\tilde{u}_{ij} = (L_{ij}, M_{ij}, U_{ij}), L_{ij} \leq M_{ij} \leq U_{ij} \; and \; L_{ij}, M_{ij}, U_{ij} \in [1/9\,, 1] \cup [1,9] \tag{2}$$

$$L_{ij} = min(B_{ijk}), \tag{3}$$

$$M_{ij} = \sqrt[n]{\prod_{k=1}^{n} B_{ijk}}\,, \tag{4}$$

$$U_{ij} = \max\,(B_{ijk})\,. \tag{5}$$

where B_{ijk} represents a judgement of expert k for the relative importance of two criteria i-j.

$$\tilde{A} = [a_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \frac{1}{\tilde{a}_{12}} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{\tilde{a}_{1n}} & \frac{1}{\tilde{a}_{2n}} & \cdots & 1 \end{bmatrix} \end{array} \tag{6}$$

where $\tilde{a}_{ij}$ *denotes a triangular fuzzy matrix for the relative importance of two criteria* C_1 *and* C_2*. Meanwhile,* $[\tilde{a}_{ij}]$ *represents the triangular fuzzy numbers by the formulas (2)-(5).*

As the preferences of experts are relatively subjective opinions, their responses could differ depending on the degree of environmental uncertainty and depending on whether the experts adopt a conservative or optimistic attitude when determining their preferences. Therefore, the degree of environmental uncertainty and the degree of experts' confidence in their preference should be taken into consideration.

For the questionnaire responses:

α is used to express the environmental uncertainty;

λ is used to express the degree of experts' confidence in their preference.

To establish the aggregate pair-wise comparison matrix, the defuzzification of the triangular fuzzy numbers derived from the fuzzy pair-wise comparison matrix is done using the following formula:

$$(a_{ij}^{\alpha})^{\lambda} = \left[\lambda \,.\, L_{ij}^{\alpha} + (1-\lambda).\, U_{ij}^{\alpha}\right], 0 \le \lambda \le 1, 0 \le \alpha \le 1 \tag{7}$$

where $L_{ij}^{\alpha} = (M_{ij} - L_{ij}).\alpha + L_{ij},$ *represents the left-end value of α-cup* a_{ij}*,* $U_{ij}^{\alpha} = U_{ij} - (U_{ij} - M_{ij}).\alpha$*, represents the right-end of α-cup for α-cup for* a_{ij}*.*

Consequently the aggregate pair-wise comparison matrix is established as follows:

$$[(A^{\alpha})^{\lambda} = [(\mathrm{a_{ij}})^{\lambda}] = \begin{array}{c} \\ \mathrm{C_1} \\ \mathrm{C_2} \\ : \\ \mathrm{C_n} \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & (a^{\alpha}{}_{12})^{\lambda} & \cdots & (a^{\alpha}{}_{1\mathrm{n}})^{\lambda} \\ (a^{\alpha}{}_{21})^{\lambda} & 1 & \cdots & (a^{\alpha}{}_{2\mathrm{n}})^{\lambda} \\ : & : & : & : \\ (a^{\alpha}{}_{\mathrm{n}1})^{\lambda} & (a^{\alpha}{}_{2\mathrm{n}})^{\lambda} & \cdots & 1 \end{bmatrix} \end{array} \tag{8}$$

Then the Eigenvector method is used for weight calculation. Eigen value and Eigenvector are calculated for each aggregate pair-wise comparison matrix at each level as follows:

$$(A^{\alpha})^{\lambda} \cdot W = \bar{\lambda}\max . W, \tag{9}$$

$$[(A^{\alpha})^{\lambda} - \bar{\lambda}\max] . W. \tag{10}$$

where W denotes the Eigenvector of $(A^{\alpha})^{\lambda}$, $0 \leq \lambda \leq 1, 0 \leq \alpha \leq 1$.

One of the main issues that affect the validity and the credibility of prioritisation is the consistency of decision makers' judgements. Lacking the mechanism to test the consistency of the comparison matrix can lead to invalid priorities (Abdul Moneim, 2008).

To verify the consistency of the comparison matrix, the consistency index (CI) and consistency ratio (CR) for each aggregate pair-wise comparison matrix at each level are calculated using Saaty's method. This method has been proposed by Saaty in 1988 to measure the inconsistency of the pair-wise comparison matrix (Vachajitpan, 2004). It defines the consistency ratio (CR) as a ratio between the consistency of a given evaluation matrix (consistency index CI) and the consistency of a random matrix (RI). As presented in table 4.1, the RI is the random index representing the consistency of a randomly generated pair-wise comparison matrix. The CR of a decision should not exceed 0.1. In the case where CR exceeds 0.1, the comparison matrix is considered inconsistent and should be improved (Meixner, 2009). For any metrics at any level, if the value of the Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, the pair-wise comparison processes should be repeated until the consistency ratio is less than 0.1.

CI and RI are calculated as follows:

$$CI = \frac{\bar{\lambda}max - n}{n-1} \tag{11}$$

$$CR = \frac{CI}{RI} \tag{12}$$

where RI represents the average consistency index over numerous random entries of same order reciprocal matrices.

Table 4.1: Random Consistency Index (RI) for different number of criteria (n)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

(Source: Al-Harbi, 2001)

4- Assigning a performance rate for each attribute using a performance rating scale

A five point performance rating scale (very poor, poor, good, very good and excellent) is established to evaluate SC operations' performance. SC performance measurement attributes are benchmarked to this performance rating scale. A performance rate (0.2, 0.4, 0.6, 0.8 or 1) is assigned for each attribute throughout the hierarchy of supply chain, where:

0.2 denotes very poor performance,

0.4 denotes poor performance,

0.6 denotes good performance,

0.8 denotes very good performance and

1 denotes excellent performance with respect to the performance rating scale.

5- Aggregating the performance and calculating supply chain index (SCI)

In MCDM problems, decision makers associate different importance weights with different criteria at different levels. Then, the weights of criteria of different levels are aggregated to obtain final weights of the decision alternatives. Many approaches have been developed to aggregate the performance from multi-criteria expressions; such as: the weighted mean aggregation operator, to handle hierarchical links, the Choquet integral operator, for taking interactions into account, and the AHP technique, to quantify the weights and the performance elementary expression (Berrah and Clivillé, 2007).

In the proposed SCOR FAHP technique, the weighted average aggregation method is used to aggregate the performance of all SC performance measurement attributes. After determining the performance rate (R) and the relative weight (W) of each attribute, the weighted rate (WR) of each attribute is calculated by multiplying the relative weight of each attribute by its performance rate.

$$WR = W * R \tag{13}$$

where W = the weight of the attribute and R = the assigned performance rate for the attribute

Then, the weighted rates of all performance measurement attributes are aggregated in order to obtain the overall SC operations' performance in terms of SC index (SCI). This index reveals the overall SC performance according to an interval based performance scale: [0.0<R<=0.2], [0.2<R<=0.4], [0.4<R<=0.6], [0.6<R<=0.8], [0.8<R<=1]; where R denotes value of the SCI, [0.0<R<=0.2] denotes very poor performance, [0.2<R<=0.4] denotes poor performance, [0.4<R<=0.6] denotes good performance, [0.6<R<=0.8] denotes very good performance and [0.8<R<=1] denotes excellent performance.

4.3 Framework for the developed performance measurement method to link SC operations' performance to a company's financial strategy

As stated earlier, SC performance is modelled according to the SCOR model standard performance matrix with its five main SC performance measures. The performance rates of all measurement attributes are aggregated - using the averaging aggregation method - throughout the hierarchy of the SC to determine the performance rate of the SC performance measurement attributes at the top level (reliability, responsiveness, agility, cost and asset management).

The weighted rates of the five main SC performance measures are then aggregated using DS/AHP method to determine the company's SCFLI. This index is different from SCI that was developed to evaluate SC operations' performance. SCI assigns a relative importance weight for SC performance measurement attribute at different levels from the lowest implementation level till the configuration level. While it assigns equal weight (20%) in the aggregation procedure to the five main SC performance measures at the top level. The performance rates of the five main SC performance measures at the top level are aggregated from the weighted rates of their sub measures at the lowest levels in the hierarchy.

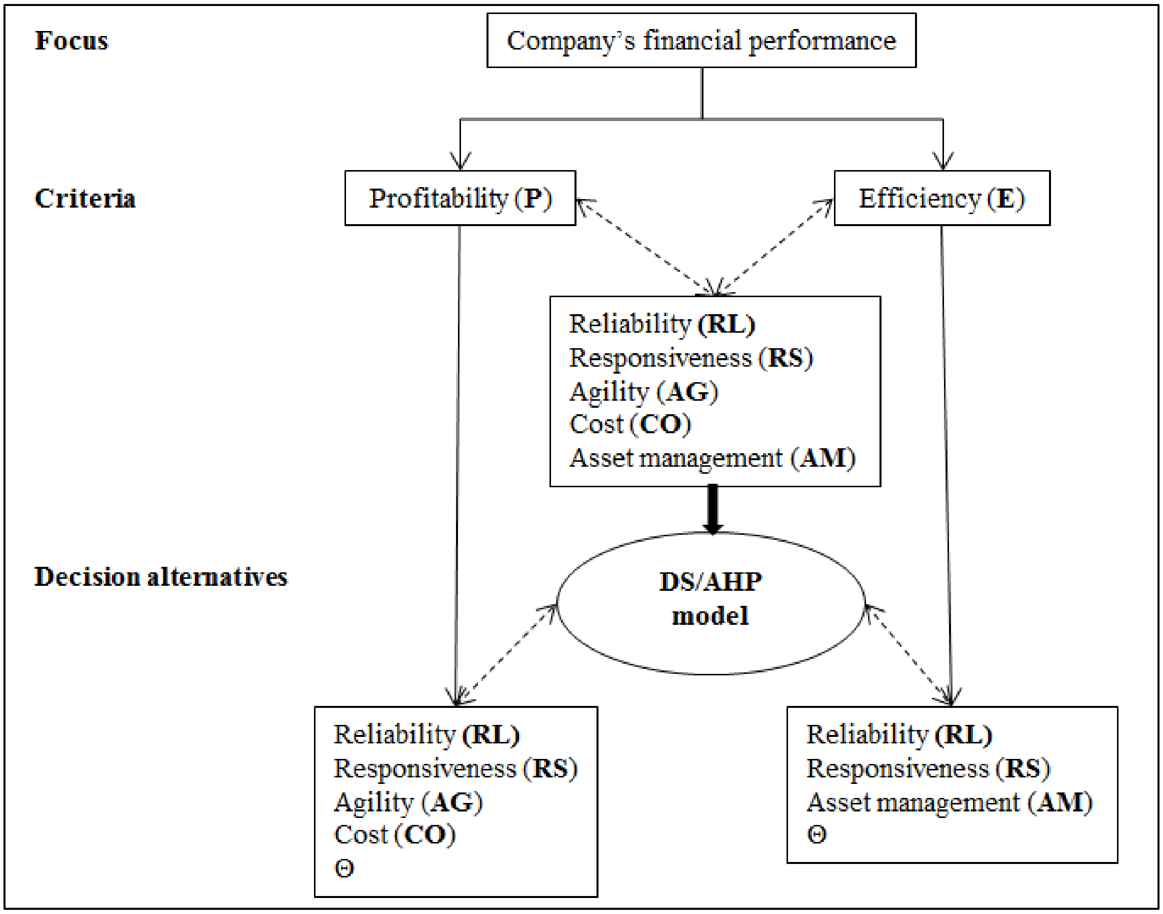
SCFLI adjusts the performance rate of the five main SC performance measures at the top level by their relative importance weights according to the company's short-term strategic financial objectives. These weights quantify the respective contributions of the SC performance measures to the overall financial performance.

The procedures for the developed performance measurement method are illustrated in the following steps, and then a numerical example will be conducted to demonstrate the developed method:

Step one: Du Pont ratio for the company is calculated and then compared to the industrial average to reveal the company's overall financial performance relative to the industrial average and highlight financial performance factors that need improvement. Based on the result of Du Pont ratio analysis, the priorities of financial performance factors (profitability and efficiency) are determined using a pair-wise comparison method.

Step two: To link SC operations' performance to the priorities of the financial performance, the relative importance weights of the five main SC performance measures can be determined with respect to the priorities of the financial performance factors using DS/AHP model. Since the company's financial performance components (revenue, cost and assets) are classified into profitability factor and efficiency factor based on Du Pont analysis, the five main SC performance measures (reliability, responsiveness, agility, cost and asset) can drive these financial performance components.

Figure 4.3 illustrates the developed hierarchy framework to link SC operations' performance to the priorities of the financial performance. Using DS/AHP model, the company does not need to consider all decision alternatives (D.A.'s) (i.e., reliability (RL), responsiveness (RS), agility (AG), cost (CO) and asset management (AM)), instead it considers groups of D.A.'s for each financial performance criterion (i.e. profitability (P) and efficiency (E)). The selected group of D.A.'s that can drive each financial performance criterion is considered based on the Presutti Jr. and Mawhinney method (see figure 3.4). As demonstrated in figure 4.3, SC performance measures that can drive profitability components (revenue and cost) are: reliability, responsiveness, agility and cost while SC performance measures that can drive efficiency components (revenue and asset) are: reliability, responsiveness and asset management.



Where: Θ is the frame of discernment which represents all decision alternatives (D.A.'s)

(Source: The author, further developed from: Elgazzar et al., 2012a)

Figure 4.3: The developed hierarchy framework to link supply chain operations' performance to the financial performance using DS/AHP model

Step three: To evaluate the efficiency and the effectiveness of current SC operational strategy, the proposed SCFLI is calculated for the company in order to reflect the extent to which SC operations' performance is linked to the company's short-term strategic financial objectives.

To calculate SCFLI, the performance rate which is assigned for each of the five main SC performance measures based on the SCOR model's SC performance index (SCI) is adjusted by the relative importance weights of these measures. By multiplying the relative importance weight of each measure by its performance rate, the weighted rate of each performance measure is determined. The weighted rates of all performance measures are then aggregated to determine the company's SCFLI.

Step four: Having evaluated and analysed its current financial performance and SC operations' performance, the company is now in a position to formulate its new SC operational strategy based on the priorities of financial performance with respect to the relative importance weights of the main SC performance measures. According to SCOR Model standard performance metrics, each SC performance measurement attribute corresponds to specific processes in the SC. Based on the relative importance weights of SC performance measures, the company can identify the related processes that need improvement and their corresponding performance indicators to align with SC operational strategy, and consequently with the company's short-term strategic financial objectives.

Step five: At the end of the accounting period, SCFLI is calculated again to evaluate the efficiency and the effectiveness of the newly developed SC operational strategy in contributing to achieving the company's short-term strategic financial objectives.

Calculating this index at the end of the period reflects the extent to which SC operations' performance is linked to the company's short-term strategic financial objectives for this period. This index also can be used as an effective SCM tool as it can be calculated at any time during the period hence allowing the company to get continuous feedback on SC operational strategy and take the necessary corrective actions for better results by the end of the period. By analysing this index, a company can trace SC processes that still need improvement enabling greater control of daily SC operations.

Step six: Du Pont ratio is calculated by the end of the accounting period to test the impact of SC operations' performance on enhancing the company's overall financial performance.

4.4 Numerical example

In this section, a numerical example is developed and analysed by the researcher to demonstrate the developed research method. The example concerns XYZ Company performance relative to the industry average. The measurement algorithm is carried out by using Microsoft Excel Spreadsheets. The procedures for applying the developed method to this numerical example are described in the following steps (Elgazzar et al., 2012a):

Step one: Evaluating current financial performance and determining the priorities of financial performance factors:

For XYZ Company, financial data relating to its total revenue, costs, net profit and total assets are extracted from its financial statements at the end of an accounting period (period 1). The benchmark in terms of industry average for this company is also provided (table 4.2).

Du Pont ratio for XYZ Company is calculated and compared to the industrial average. As illustrated in table 4.2, the company's return on asset ratio is below the industry average. To highlight the factors behind this low performance, the Du Pont ratio is broken into its components (Net Profit Margin and Total Assets Turnover) reflecting the company's financial performance in terms of profitability and operating efficiency.

The analysis reveals that the company has a high Net Profit Margin resulting in higher than average profitability. However, the company's financial performance in terms of efficiency is far below the industry average which highlights that the company has a problem in generating sales from assets employed in business.

Table 4.2: XYZ Company's financial performance compared to the industry average at the end of period (1)

	XYZ company	Industry average
Sales	$5000	$5500
Total Cost	$3700	$4080
Net Income	$1300	$1420
Total Assets	$8000	$6250
ROA	0.163	0.227
Net Profit Margin (%)	26%	25.8%
Total Asset Turnover (times)	0.63	0.88

Based on the result of Du Pont ratio analysis, the focus area for enhancing the financial performance can be determined by repositioning the priorities of financial performance factors (profitability and efficiency). To reposition the priorities of these factors, a pair-wise comparison is conducted using a pair-wise questionnaire. As presented in figure 4.4, the questionnaire is designed based on a scale with the values 1, 3, 5, 7 and 9, where 1 denotes equally important, 3 for slightly more important, 5 for strongly more important, 7 for demonstrably more important and 9 for absolutely more important.

<table>
<tr><td>With respect to (financial performance)</td><td colspan="9">Importance or preference of one factor over another</td><td></td></tr>
<tr><td>Attribute</td><td>Absolutely more important (9)</td><td>Demonstrably more important (7)</td><td>strongly more important (5)</td><td>Slightly more Important (3)</td><td>Equally important (1)</td><td>Slightly more Important (3)</td><td>strongly more important (5)</td><td>Demonstrably more important (7)</td><td>Absolutely more important (9)</td><td>Attribute</td></tr>
<tr><td>Profitability (P)</td><td colspan="9"></td><td>Efficiency (E)</td></tr>
</table>

Figure 4.4: Questionnaire form to facilitate comparison of the importance of financial performance factors

A group of decision makers is assembled following the criteria that have been mentioned in section (4.2). This group of decision makers is asked to assign the priorities of the financial performance factors – with respect to Du Pont analysis results - using the pair-wise questionnaire's scale (see figure 4.4).

For this numerical example, we assume that four experts respond to the questionnaire and responses are as presented in table 4.3. Since, the results of Du Pont analysis reveals that the company's *Total Assets Turnover* is far below the industry average, the first expert (EXP.1) strongly believes that to enhance the financial performance, it is more important for the company to focus on improving operating efficiency than increasing profitability. Both second and third experts (EXP.2 and EXP.3) consider that improving operating efficiency is demonstrably more important; while the fourth one (EXP.4) suggests that focusing on the operating efficiency is absolutely more important.

Table 4.3: The experts' consolidated responses on the questionnaire for assigning the priorities of the financial performance factors

	EXP.1	EXP.2	EXP.3	EXP.4	G.MEAN
P VS. E	0.2	0.143	0.143	0.111	0.146

The geometric mean (G.MEAN) is used to aggregate the experts' responses in order to establish the pair wise comparison matrix following the traditional AHP method. As shown below, based on the G.MEAN value, the pair-wise comparison matrix is established to express the consolidated opinions of the experts.

$$\begin{array}{c|cc|} & P & E \\ P & 1 & 0.146 \\ E & 6.58 & 1 \end{array}$$

where 0.146 is the G.MEAN value while 6.58 is the reciprocal value of the G.MEAN

For this pair-wise comparison matrix, the Eigenvector method is used for weight calculation and the priorities of the financial performance factors are determined as follows: Profitability (P) 12.7% and Efficiency (E) 87.3%

For this company, the higher priority to enhance financial performance is given to the efficiency factor with a priority weight of 87.3% compared to only 12.7% assigned to the profitability factor.

The results reveal that for the new accounting period (period 2); enhancing the financial performance can be achieved through focusing on SC performance measures that drive efficiency components.

Step two: Determining the relative importance weights of the five main SC performance measures with respect to the financial performance priorities:

Since the priorities of the financial performance factors are determined, the company now is in the position to link SC operational strategy to the focus area of enhancing the financial performance. To create this link, DS/AHP approach is conducted to determine the relative importance weights of the main SC performance measures (RL, RS, AG, CO, AM) with respect to the priorities of financial performance factors.

Based on the Presutti Jr. and Mawhinney (2007) method, groups of D.A.'s for each financial performance criterion (P, E) are selected and consequently the hierarchy of the problem is established (see figure 4.3).

DS/AHP model is based on a measure of favourability of knowledge that decision makers have about a group of D.A.'s compared with the frame of discernment (θ) within the context of each specific criterion. For each criterion there are certain groups of D.A.'s, including θ, about which the decision maker can express some degree of favourable knowledge (Beynon et al., 2000).

The group of decision makers is asked to rank the five main SC performance measures priority - with respect to each financial performance criterion - using the following 4 unit scale as a basis for discriminating levels of preference: 3 for slightly more important, 5 for strongly more important, 7 for demonstrably more important and 9 for absolutely more important.

Table 4.4 illustrates the initial knowledge matrices which represent the consolidated opinions of the decision makers for ranking the five main SC performance measures priority with regard to each financial performance criterion.

In the knowledge matrix, the values in the final column are the measures of favourability of certain groups of D.A. in each row with respect to θ. For example in P knowledge matrix, CO is viewed as demonstrably more important compared to θ. The zeros which appear in the knowledge matrix indicate no attempt to assert preference between SC performance measures, (e.g. RL to CO); this assertion can be made indirectly through knowledge of the favourability of RL to θ and CO to θ relatively. The indirect knowledge is that CO is considered more important to RL in relation to θ.

Table 4.4: Initial knowledge matrices for financial performance criteria

Initial knowledge matrix for profitability (P)					
P	RL	RS	AG	CO	θ
RL	1	0	0	0	7.4539
RS	0	1	0	0	7.4539
AG	0	0	1	0	6.43526
CO	0	0	0	1	7.93725
θ	0.13416	0.13416	0.15539	0.12599	1

Initial knowledge matrix for efficiency (E)				
E	RL	RS	AM	θ
RL	1	0	0	3.87298
RS	0	1	0	3.40866
AM	0	0	1	9
θ	0.2582	0.29337	0.11	1

It is important to note that although DS/AHP method is adapted from the AHP method:

- This method does not use the equally preferred rating of 1 (as in the AHP method); this being a consequence of evaluating groups of D.A.'s vis a vis the frame of discernment.
- Since no pair-wise comparisons of D.A.'s are performed but relating groups of D.A.'s to θ, there are no consistency problems within a criterion, as long as no two proper subsets of θ considered in a criteria have a D.A.

Then, according to DS/AHP method the priority values of financial performance factors are incorporated into each of the initial decision knowledge matrices. As shown in table 4.5, the initial knowledge matrices are influenced by the priority values of financial performance factors. This is done by multiplying the elements in the last column (except the last entry in that column) by the respective importance value for that criterion (noting that the importance values do not affect the elements in the matrix which are either zero or one).

Table 4.5: Knowledge matrices for financial performance criteria after influence of their priority rating

Knowledge matrix for profitability (P) after influence of its priority rating						**Knowledge matrix for efficiency (E) after influence of its priority rating**				
P	RL	RS	AG	CO	θ	**E**	RL	RS	AM	θ
RL	1	0	0	0	0.949441	RL	1	0	0	3.37966
RS	0	1	0	0	0.949441	RS	0	1	0	2.974481
AG	0	0	1	0	0.819691	AM	0	0	1	7.853626
CO	0	0	0	1	1.011007	θ	0.2959	0.3362	0.1273	1
θ	1.0533	1.0533	1.21997	0.9891	1					

Using the knowledge matrices for each of the criteria, we can produce normalised knowledge vectors as illustrated in table 4.6, following the traditional AHP method.

Table 4.6: The normalised knowledge vectors of the main SC performance measures for each of the financial performance factors

Profitability(P)		**Efficiency (E)**	
RL	16.6%	RL	21.2%
RS	16.6%	RS	18.7%
AG	14.3%	AM	49.3%
CO	17.6%	θ	10.9%
θ	34.9%		

Then, these normalised pieces of evidence can be combined using Dempster's rule of combination. The D–S combination rule determines the joint $m_{1\text{-}2}$ from the aggregation of two basic probability assignments (BPA) m_1 and m_2 by following equation:

$$m_{1-2}(A) = \frac{\sum_{B \cap C = A} m_1(B) m_2(C)}{1-K} \quad when\ A \neq \Phi;\ and\ m_{1-2}(\Phi) = 0 \qquad (14)$$

The denominator (1-K) is a normalisation factor, which helps aggregation by completely ignoring the conflicting evidence where K is the degree of conflict in two sources of evidences.

$$K = \sum_{B \cap C = \Phi} m_1(B) m_2(C) \qquad (15)$$

By applying D–S rule of combination on sources of information P and E, the following data is generated:

m1(P) \ m2(E)	$m2(E)_{RL}$= 0.165709	$m2(E)_{RS}$= 0.165709	$m2(E)_{AG}$= 0.143063	$m2(E)_{CO}$= 0.176454	$m2(E)_{AM}$ = 0	$m2(E)_{\theta}$= 0.349066
$m2(E)_{RL}$=0.212026	0.035135 {RL}	0.035135 {Φ}	0.030333 {Φ}	0.037413 { Φ}	0 { Φ}	0.074011 {RL}
$m2(E)_{RS}$=0.186607	0.030922 { Φ}	0.030922 {RS}	0.026697 { Φ}	0.032928 { Φ}	0 { Φ}	0.065138 {RS}
$m2(E)_{AG}$ =0	0 { Φ}	0 { Φ}	0 {AG}	0 {Φ}	0 { Φ}	0 {AG}
$m2(E)_{CO}$ =0	0 { Φ}	0 { Φ}	0 { Φ}	0 {CO}	0 { Φ}	0 {CO}
$m2(E)_{AM}$=0.492705	0.081645 { Φ}	0.081645 { Φ}	0.070488 { Φ}	0.08694 { Φ}	0 {AM}	0.171986 {AM}
$m2(E)_{\theta}$=0.108662	0.018006 {RL}	0.018006 {RS}	0.015545 {AG}	0.019174 {CO}	0 {AM}	0.03793 {θ}

Degree of conflict (K) =0.514146

Normalised factor (1-K) =0.485854

$m_{1\text{-}2}(A)_{RL} = 0.127152/0.485854=0.261708$

$m_{1\text{-}2}(A)_{RS} = 0.114067/0.485854=0.234775$

$m_{1\text{-}2}(A)_{AG} = 0.015545/0.485854=0.031996$

$m_{1\text{-}2}(A)_{CO} = 0.019174/0.485854=0.039464$

$m_{1\text{-}2}(A)_{AM} = 0.171986/0.485854=0.353987$

$m_{1\text{-}2}(A)_{\theta} = 0.03793/0.485854=0.078069$

And then, the overall BPA for SC performance measures ($m_{sc\ performance\ measures}$) can be constructed and consequently the relative importance weights of the five main SC performance measurement attributes are ranked as illustrated in table 4.7 indicating that AM is the most important SC performance criteria to focus on for the purpose of linking SC operations' performance to the company's short-term strategic financial priorities.

Table 4.7: The relative importance weights of the main SC performance measures with respect to the financial performance's priorities

Subsets	SUMm1(P)M2(E)	$m_{sc\ performance\ measures}$	Weight(W)	Priority
RL	0.127152	0.261708	26%	2
RS	0.114067	0.234775	24%	3
AG	0.015545	0.031996	3%	5
CO	0.019174	0.039464	4%	4
AM	0.171986	0.353987	35%	1
θ	0.03793	0.078069		

Also from table 4.7 it can be noticed that the sum of the relative importance weights of the five main SC performance measures is not equal to one (it equals 0.92). As mentioned before, under the probability framework, the sum of probabilities of all possible values of a variable equals one. Using DS/AHP model the related measure of ignorance can be calculated enabling companies to have greater control on their decisions as companies need only to give decisions according to the factors that they can control and have information and data about. This ignorance factor reflects the influence weight of the other unknown or uncontrollable factors that can impact the company's financial performance. In this example, the ignorance factor is 0.08; however this factor is subject to change according to the environmental uncertainty level and the degree of the experts' confidence in their preference based on information and data available.

Step three: Evaluating the efficiency and the effectiveness of current SC operational strategy

To evaluate the efficiency and the effectiveness of current SC strategy, the SCFLI is calculated for the company.

Based on the proposed SCOR FAHP technique, SC operations' performance is evaluated by assigning performance rate (0.2, 0.4, 0.6, 0.8, or 1) for each of the SC performance measurement attributes throughout the hierarchy of SC, from the process element levels till the configuration level, to assess the performance of the company's SC operations with respect to the established performance rating scale.

Then, the performance rates of all measurement attributes are adjusted by their relative importance weights. The weighted rates of all measurement attributes from the lowest implementation level till the configuration level are aggregated- using averaging aggregation method- throughout the hierarchy of the SC to determine the performance rate of the five main SC performance measures at the top level (RL, RS, AG, CO, AM). Where 0.2 denotes very poor performance, 0.4 denotes poor performance, 0.6 denotes good performance, 0.8 denotes very good performance and 1 denotes excellent performance with respect to the performance rating scale.

To calculate SCFLI, the performance rates which are assigned for the five main SC performance measures based on the SCOR FAHP technique are adjusted by the relative importance weights of these measures.

By multiplying the relative importance weight of each measure (W) by its performance rate (R), the weighted rate (WR) of each performance measure is determined as shown in table 4.8.

Table 4.8: The aggregated weighted rates of the five main SC performance measures before applying the new SC operational strategy

Measure	R	W	WR
RL	0.8	26%	0.208
RS	0.8	24%	0.192
AG	1	3%	0.03
CO	0.8	4%	0.032
AM	0.6	35%	0.21
SUM	4	92%	0.672

The weighted rates of all performance measures are then aggregated and the company's SCFLI is calculated as follows:

$$\text{Supply chain financial link index (SCFLI)} = \frac{\sum WR}{\sum W} = \frac{0.672}{0.92} = 0.73 \qquad (16)$$

$$\text{SC index (SCI)} = \frac{\sum R}{N} = \frac{4}{5} = 0.8 \qquad (17)$$

where N represents the number of the main SC performance measures.

SCI is 0.8, by adjusting this index with the relative importance weights of the five main SC performance measures, the company's SCFLI is calculated to be 0.73 to reflect the extent to which current SC operations' performance are linked to the company's financial priorities.

Step four: Formulating new SC operational strategy based on the company's short-term strategic financial priorities:

Since the relative importance weight of each SC performance measure is determined, the company can now identify SC processes that need improvement and their corresponding performance indicators based on SCOR Model standard performance metrics.

For XYZ Company, as the company's short-term strategic financial objective is to improve its efficiency particularly through managing its assets, the most suitable SC operational strategy to align with this strategic financial objective is to focus on enhancing the processes to which asset management performance measures correspond. According to XYZ Company's strategic priorities, the main goals of its SC operational strategy should be managing SC assets.

For example: To accomplish the aim of managing SC assets, the company focuses SC operational strategy on managing SC fixed and current assets. Then, the company determines the objectives and the action plans needed to implement this strategy.

Table 4.9 illustrates the objectives and plan of action at level one of the SCOR model to accomplish the aim of managing SC assets. Also, key performance indicators to evaluate the effectiveness of accomplishing this aim are identified based on SCOR model level 1 metrics.

Table 4.9: Supply chain operational strategy at level one of the SCOR model

Strategic aim	Level 1 objectives	Level 1 plan of action	Responsibilities	Key performance indicators at level 1 metrics
Managing SC Assets	Reducing cash-to-cash cycle time by 10 days	Review the collection policy and establish procedures to optimise accounts receivable management	Financial department	Cash-to-Cash Cycle Time
	Increasing return on supply chain fixed assets by 7 percentage points.	- Reducing downtime to 7% - Increasing the operating rate to 95% of potential full capacity output - Reducing % of spoilage material to 2%	Engineering department and Production department	Return on Supply Chain Fixed Assets
	Increasing return on working capital by 5 percentage points.	Developing an effective inventory management system	Commercial department	Return on Working Capital

Step five: Evaluating the efficiency and the effectiveness of the new SC operational strategy in contributing to achieving the company's short-term strategic financial objectives:

At the end of period 2, the performance rates (R) of the five main SC performance measures are determined and then adjusted by their relative importance weights (W). Table 4.10 illustrates the weighted rate (WR) of each SC performance measure after applying the new SC operational strategy.

Table 4.10: The aggregated weighted rates of the five main SC performance measures after applying the new SC operational strategy

Measure	R	W	WR
RL	0.8	26%	0.208
RS	0.8	24%	0.192
AG	1	3%	0.03
CO	0.8	4%	0.032
AM	0.8	35%	0.28
SUM	4.2	92%	0.742

The weighted rates of the five main SC performance measures are then aggregated and SCFLI is calculated again to measure and evaluate the significant contribution of the new developed SC operational strategy in achieving the company's short-term strategic financial objectives.

At the end of period 2, SCI of XYZ Company is 0.84 while the company's SCFLI is 0.81. SCFLI increased by approximately 8% revealing improvement in the efficiency and the effectiveness of SC operational strategy in connecting to the company's short-term strategic financial objectives. Although SCI measures the change in SC operations' performance; it is unable to trace the impact of such change on the company's overall financial performance. This index ignores the relative influence weight of SC operations' performance on enhancing the financial performance as it assumes that the five main SC performance measures are equally weighted.

Alternatively assuming that at the end of period 2, the performance rate (R) of supply chain reliability (RL) dropped to 0.6. In this case SCI would remain 0.8 revealing no change in the SC operations' performance; while SCFLI would be 0.75 showing improvement in the performance by 2%. According to this assumption, although there are changes in SC operations' performance after applying the new SC operational strategy, SCI cannot capture the impact of these changes on the company's financial performance as it doesn't take into consideration the relative importance weights of the five main SC performance measures with respect to the priorities of financial performance factors.

Step six: Determining the impact of SC operations' performance on enhancing the financial performance of the company:

By the end of period 2, the Du Pont ratio for the company is calculated again and analysed to determine the impact of improving SC operations' performance on enhancing the company's overall performance.

The company's SC operations' performance and the overall financial performance before applying the new SC operational strategy (period 1) and after applying the new SC operational strategy (period 2) are summarised in table 4.11.

Table 4.11: SC operations' performance and the financial performance before and after applying the new SC operational strategy

Measure	**Period 1**			**Period 2**			**Change direction**
SC operations' performance							
	R	W	WR	R	W	WR	
RL	0.8	26%	0.208	0.8	26%	0.208	No change
RS	0.8	24%	0.192	0.8	24%	0.192	No change
AG	1	3%	0.03	1	3%	0.03	No change
CO	0.8	4%	0.032	0.8	4%	0.032	No change
AM	0.6	35%	0.21	0.8	35%	0.28	Favourable
SCI	0.8			0.82			Favourable
SCFLI	0.73			0.81			Favourable
Financial performance							
ROA	0.163			0.2025			Favourable
Net Profit Margin (%)	26%			27%			Almost no change
Total Asset Turnover (times)	0.63			0.75			Favourable

Comparing Du Pont results at the end of period 2 to the results at the end of period 1 shows improvement in the Total Asset Turnover which reflects the impact of the SC operations' performance on enhancing the company's overall financial performance.

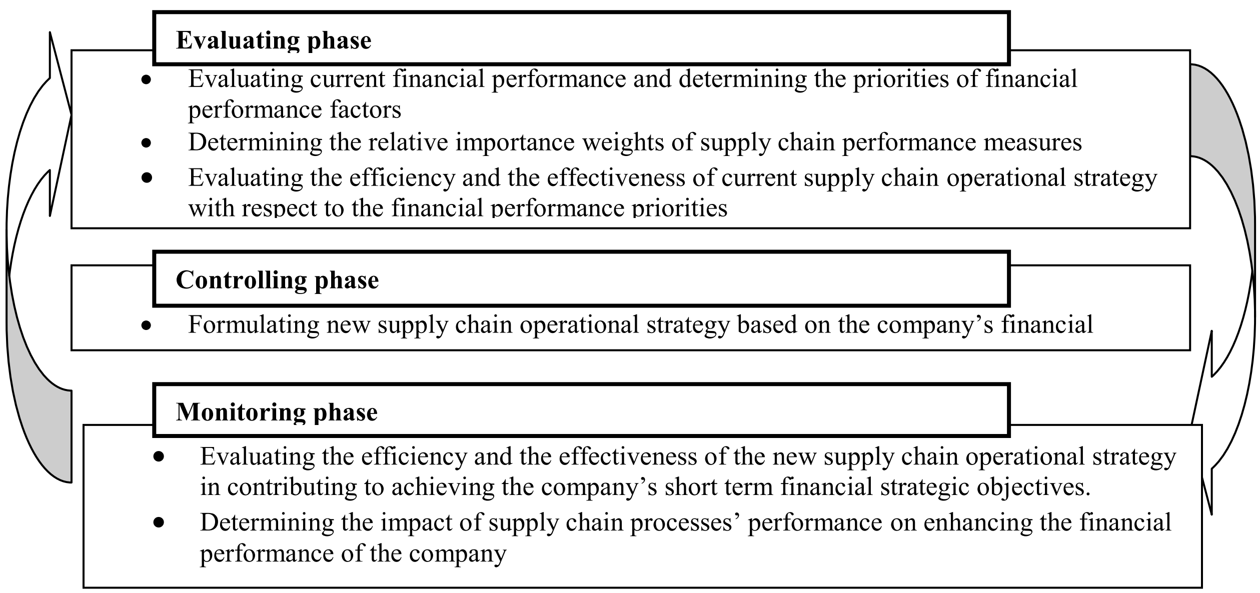
4.4 Conclusion

In this chapter, the framework of the SCOR FAHP technique for measuring SC operations' performance was presented. The proposed technique provides an effective tool to manage and quantify SC operations' performance through quantifying: SC measurement criteria, environmental uncertainty and subjective judgements of SC performance evaluators. This technique starts by analysing the structure and the characteristics of a targeted supply chain. Then, supply chain processes are identified and mapped to the SCOR model's standard description of SC processes. Consequently, the corresponding performance measurement attributes of these mapped processes are identified based on the standard performance metrics of SCOR model. A benchmarking process is conducted to assign a performance rate for each performance measurement attribute. Finally, based on the FAHP method, the weighted rate of each attribute is calculated and then aggregated across all SC performance measurement attributes using the weighted average aggregation method to determine the performance index of a company's supply chain. Since each SC performance measurement attribute has a weighted rate and corresponds to specific processes in the SC, SC processes that need improvement can be identified and the overall SC performance, in terms of SCI, can be evaluated.

In addition, the framework of the performance measurement method to link SC operations' performance to a company's financial strategy was developed and illustrated in this chapter using a numerical example. SC performance metrics are linked to the priorities of the company's financial performance. This method enables companies to connect SC operations' performance to the company's short-term strategic financial objectives through evaluating current SC operational strategy and then formulating the new SC operational strategy based on the priorities of the financial performance in the short-term for achieving improvement in the company's profitability as the primary long term financial goal.

SCFLI was introduced to test the extent to which SC operations' performance is linked to the company's short-term strategic financial objectives. This index provides organisations with an effective SCM tool to evaluate, monitor and control SC operations' performance in order to enhance SC operational strategy for better alignment with the company's financial strategy.

The complete procedures of linking SC operations' performance to the company's strategic financial objectives are summarised in figure 4.5. In the next two chapters, the applicability of the research method will be illustrated through conducting a deductive qualitative case study of an Egyptian bottled water company.



(Source: The author, Elgazzar et al., 2012a)

Figure 4.5: Linking SC operations' performance to the company's strategic financial objectives

CHAPTER FIVE - CASE STUDY: DEVELOPMENT AND FINDINGS

5.1 Introduction

The methodology for conducting the case study was outlined in chapter three. A full picture of the design and implementation of the case study research method was provided. The detailed process was discussed and reviewed starting from how to design a case study through to writing up a case report. In chapter four, a numerical example was presented to illustrate the research framework before implementation on a real case study. In this chapter, the application procedures of the research method on the real case study are presented.

Five phases are carried out to conduct the case study, namely: case design and preparation for data collection, introductory phase, establishing the SCOR FAHP technique, implementation phase and data analysis phase. In the first phase, the research questions and propositions are identified, the unit of analysis is determined and the case is selected. The introductory phase provides an overview of the case study company and analyses its supply chain. In the third phase, the proposed SCOR FAHP technique is established for the case study company. During the implementation phase, a software (SW) application system is designed to enable the application of the developed research method. Finally, the data collected during the implementation phase is analysed to develop the conclusions and prepare the case study report.

5.2 Phase one: Case design and preparation for data collection

In this section, the first phase of the case study is presented (case design and preparation for data collection). The Egyptian bottled water sector is described and analysed as the selected sector to apply the proposed methodology. In this phase, case study nominations from this sector are screened in order to select the most appropriate case to be conducted, upon which the case study protocol is developed.

5.2.1 The Egyptian bottled water industry

According to the International Bottled Water Association (IBWA) (2005, p.6), bottled water is defined as *"water that is intended for human consumption and that is sealed in bottles or other containers with no added ingredients except that it may optionally contain safe and suitable antimicrobial agents"*. This sector was chosen for the following reasons:

1. There is limited variation in the manufacturing process of bottled water; therefore accessing one brand in order to identify supply chain processes and relevant performance measures allows generalisation.
2. The nature of the supply chain in this industry with its many stages and processes, starting from the water source and ending with satisfying the customer order, makes it a rich supply chain to be studied.
3. Bottled water is the second largest sector by volume in the Egyptian soft drinks market (Abd El-Salam et al., 2008)
4. In recent years, this sector has been found to be noncompliant with the required national and international quality standards (Leila, 2008; Saleh, 2008).
5. Egypt has the highest kidney failure rate in the world, mainly because of the lack of a reliable source of clean drinkable water (Fine waters, 2008).

A detailed analysis of the Egyptian bottled water industry is presented below following the external environment analysis approach reviewed in section 2.4.1. The analysis starts by presenting the overall performance of the Egyptian bottled water sector and the market's major players. Then, the general environmental elements affecting the Egyptian bottled water industry are illustrated. Finally, the competitive environment and the key factors influencing the market are analysed.

Evaluation of the overall performance of the Egyptian bottled water sector and identification of the market's major players

The Egyptian bottled water sector registered the highest growth in total sales volume and values terms in 2010. Total volume increased by 17.5% compared to 15.5% in 2009. The compound annual growth rate (CAGR) was 15.4% over the last five years (2005:2009) as a whole and it is expected that this rate will grow further to reach 16.4% over the coming five years (2011: 2015). Total sales value increased by 17.2% in 2010 compared to 10.4% in 2009. The industry sales value reached 4.2 billion EGP in 2010 and is expected to grow by an 8% constant value compound annual growth rate (CAGR) to reach 6.2 billion EGP in 2015 (Euromonitor International, 2011).

There are 17 brands in the Egyptian bottled water sector; namely: Baraka, Safi, Aqua, Nestle, Schweppes, Hayat, Aqua Siwa, Mineral, Dasani, Siwa, Aquafina, Delta, S Pellegrino, Hayaweya, Volvic, Nubia, and Perrier (Euromonitor International, 2010).

The leading player is Aquafina. Aquafina enjoys a strong heritage and brand equity in Egypt and it is commonly consumed by middle-income consumers. The second ranked player in retail volume and value terms is Nestla Pure Life. It was able to capture strong retail volume and value share as it has become the choice of upper-income consumers. The third ranked player is the Dasani brand (Memrb, 2010). Figure 5.1 illustrates the Egyptian bottled water sector key players' market shares in 2009. In this figure, the companies' real names are replaced with codes for confidentiality reasons.

A		16,372,600
Share	8%	6%
Growth		-14%
Add Vol		-2,589,380

B		47,016,790
Share	15%	18%
Growth		37%
Add Vol		12,816,660

C		4,959,036
Share	3%	2%
Growth		-38%
Add Vol		-3,067,262

D		33,059,260
Share	17%	13%
Growth		-17%
Add Vol		-6,623,640

E		49,743,440
Share	18%	19%
Growth		19%
Add Vol		7,870,220

F		4,259,145
Share	2%	2%
Growth		0%
Add Vol		-19,282

G		53,682,640
Share	21%	21%
Growth		8%
Add Vol		3,945,690

H		1,417,382
Share	3%	1%
Growth		-81%
Add Vol		-6,048,787

I		24,589,900
Share	4%	10%
Growth		168%
Add Vol		15,402,026.0

(Source: Memrb, 2010)

Figure 5.1: The Egyptian bottled water sector main players' shares in 2009

General environmental analysis

The general environmental analysis provides a description of the elements in the operating environment that directly affect the Egyptian bottled water industry. It consists of four primary factors, which are social cultural, economic, technological and legal-political.

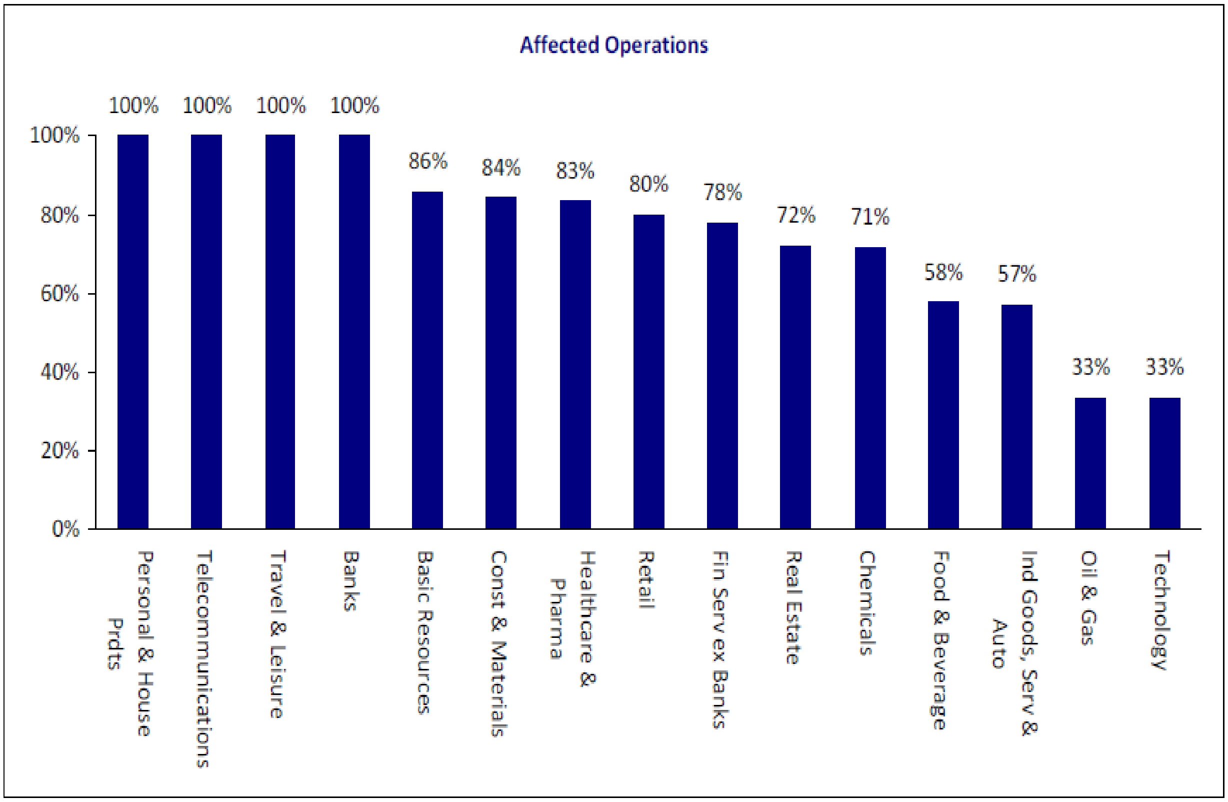
1- Social culture:

The popularity of bottled water increased dramatically in Egypt since 1996, and different customers were able to be targeted. The awareness of health and water quality was increased. Beverage preferences were changed as desire for alternatives to sodas, coffee and other beverages has increased. In addition, the drinking habits of today's youth tend to more closely resemble those of Western youth. A large segment of the population under the age of 25 provides strong and growing demand for bottled water. Youth are also more receptive to advertising than their parents, who tend to be more sceptical. This makes advertising activities by key brands more attractive to Egyptian consumers (Euromonitor International, 2009, 2010, 2011).

2- Economic dimension:

As stated earlier, bottled water in Egypt registers the highest growth in both total volume and value terms in recent years. With a construction boom and the drive to develop offerings for tourists and the popularity of hypermarkets and shopping malls, the number of outlets selling bottled water has increased dramatically and is driving stronger consumption (Euromonitor International, 2009, 2010, 2011).

At the end of January 2011, the Egyptian revolution took place. As a result of this low probability, high impact event, the Egyptian manufacturing sector witnessed instability in different business activities. Logistics activities have been dramatically affected resulting in disorder in materials, labour, information, funding and products flows such as: irregular raw material supply and fuel supply for manufacturing and transportation activities, the inability of employees to reach the workplace, difficulty in accessing distribution channels, cutting off communication networks and problems with money transfer. As a result; the manufacturing process was halted for a period in many companies while other companies exited the market. Figure 5.2 represents the percentage of companies in different sectors that were affected by the revolution. The percentages are based on the number of companies that actually disclosed information. As illustrated, in the Food and Beverage sector out of the companies that disclosed information regarding their operations 58% were affected.



(Source: Shahin and Zreik, 2011)

Figure 5.2: The percentage of companies in different Egyptian manufacturing sectors that were affected by the Egyptian revolution

3- Technological dimension:

Due to the risk of Bisphenol A used in manufacturing plastic bottles, there is a new trend towards producing Bisphenol A -Free water bottles (especially for baby bottles). The use of Bisphenol A in making baby bottles is currently banned in many countries. In addition, experts suggest one way water bottles as a new trend (especially for family gallon bottles) in order to avoid refilling plastic bottles as the risk of Bisphenol A leaching into the water is increased (Kathie, 2009).

4- Legal-political dimension:

At national level, The Consumer Protection Agency (CPA) as a main sponsor for activating the role of consumer protection associations makes analytical studies of the bottled water to ensure that bottled water manufacturing companies in Egypt meet the required standards (CPA, 2007; Leila, 2008).

At global level, The Codex Alimentarius Commission (CAC) has developed a Codex Standard for Natural Mineral Waters and an associated code of practice. CAC is the intergovernmental body initiated by the World Health Organisation (WHO) and the Food and Agricultural Organisation (FAO) for the development of internationally recognised standards for food (Lupien, 2000). The Codex Standard for Natural Mineral Waters describes the product and its labelling, compositional and quality factors, including limits for certain chemicals, hygiene, packaging and labelling. The Codex Code of Practice for Collecting, Processing and Marketing of Natural Mineral Waters provides guidance to the industry on a range of good manufacturing practices matters. Codex health and safety requirements are recognised by WHO as representing the international consensus for consumer protection and any deviation from Codex recommendations may require a scientifically-based justification, however they are not mandatory (Gleick et al., 2004).

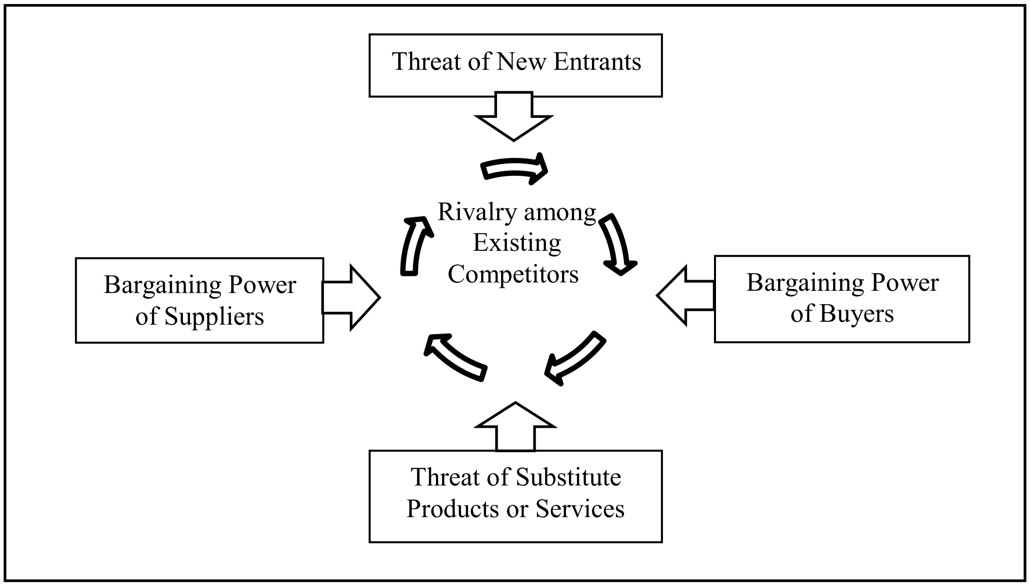
In addition, all major industry players follow strict industry standard Hazard Analysis for Critical Control Points (HACCP) health and safety guidelines. HACCP is "*a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product*" (FDA, 2011).

The competitive environment and analysis of the key factors influencing the market

Sales of bottled water continued to grow through the on-trade channel, due to four major factors. Firstly, Egypt has a very hot climate approximately eight months out of each year. Moreover, Ramadan fell in a hot summer month in 2010 and in a very hot summer month in 2011, causing a dramatic increase in sales as consumers needed to drink large amounts of water once they broke their fast at sunset (Euromonitor International, 2011). Secondly, the expansion of the retail infrastructure in the country has created more space for restaurants and coffee shops. Thirdly, the growing number of international visitors has increased the demand for bottled water as they are keen to avoid the risk of stomach infections from polluted tap water sources. Finally, the pollution of tap water in Egypt has increased the concerns about related illnesses such as stomach and kidney infections (Euromonitor International, 2010).

However, bottled water has suffered from the adverse publicity generated by media campaigns, as the government has tried to satisfy public concerns over the safety of tap water, which had a negative impact on the credibility of brands. Advertising activities by key brands such as Nestla Pure Life and Aquafina (Pepsi-Cola Egypt) were ongoing in 2008 and in 2009. They have chosen to use TV satellite channels to promote and support their brands across the Middle East. Their campaigns are intended to restore consumers' confidence in these brands and to maintain brand equity (Euromonitor International, 2009). In addition, the Egyptian bottled water sector was affected by various promotions in the Egyptian retail market resulting in an increase in sales volume but a decrease in sales value (Euromonitor International, 2011).

An analysis based on Michael Porter’s Five Forces Model was conducted to understand the competitive environment and analyse the key factors influencing the Egyptian bottled water market and the challenges facing it.



(Source: Porter, 2008)

Figure 5.3: The five forces that shape industry competition

As illustrated in figure 5.3, the five forces consist of competitive rivalry, power of suppliers, power of buyers, threat of substitutes and threat of entry. These five forces define an industry's structure and shape the nature of competition within it. The analysis of these forces helps companies within an industry to be more profitable and less vulnerable to attack (Porter, 2008).

Table 5.1 summarises the factors that affect the five forces. The extended analysis of these factors and their impact on the five forces in the Egyptian bottled water sector is presented below.

Table 5.1: The key factors affecting Porter's five forces in the Egyptian bottled water market

Factors affecting the Industry Rivalry	**Increase (decrease) the Industry Rivalry**
Industry Growth Rate	-
High Fixed Cost	+
Intermittent Over Capacity	+
Product Differences	+
Brand Identity	-
Switching Costs	+
Exit Barriers	+

Factors affecting the bargaining Power of Suppliers	Increase (decrease) the bargaining Power of Suppliers
Differentiation of Inputs	-
Switching Costs	-
Substitute Products	+
Supplier concentration relative to industry concentration	-
Factors affecting the bargaining Power of Customers (Buyers)	**Increase (decrease) the bargaining Power of Customers (Buyers)**
Differentiation of outputs	+
Switching costs	+
Factoring affect the threat of Substitute Product or Services	**Increase (decrease) the threat of Substitute Product or Services**
The relative Price performance of substitutes	+
Buyer Propensity to Substitute	-
Factors affecting the threat of New Entrants	**Increase (decrease) the threat of New Entrants**
Economies of scale	-
Capital requirements	-
Access to distribution	-
Government policy	-

(Adapted from: *what makes a good leader* site's strategic planning templates, 2009).

1- Competitive Rivalry:

Table 5.1 reveals that competitive rivalry in the Egyptian bottled water industry is high which makes the companies in this industry compete in a highly competitive market. Although, there are strong brands in the Egyptian bottled water industry such as Baraka, Nestla Pure Life, and Schweppes where the consumer has a strong brand preference, the Egyptian bottled water industry's products are essentially the same. The low switching costs in the Egyptian bottled water industry make it easy for competitors to attract customers, and as a result the risk of competitor rivalry would be higher.

The Egyptian bottled water industry is in a growth phase which leaves room for all businesses in industry to grow. However, the companies in this industry have the same capacity throughout the year while the demand varies (seasonal demand; for example the demand in summer is higher than in winter). During the periods of over capacity (too much supply; such as in winter), competitor rivalry is more likely to be increased.

In addition, fixed costs are high proportion of the total costs which makes each competitor seeking to maintain volume. Operating in the Egyptian bottled water industry requires a large capital investment in plant and equipment which creates high barriers preventing a company from exiting the industry. It is likely that competitors will be prepared to operate at a marginal profit or loss resulting in higher competitor rivalry.

2- Bargaining Power of Suppliers:

Evaluation found the power of suppliers in the Egyptian bottled water industry to be low. Although there is no alternative or substitute for suppliers' products in the Egyptian bottled water industry, suppliers' products are essentially the same. There are many suppliers selling almost the same products to manufacturers in the Egyptian bottled water industry. Changing suppliers does not require the incurring of switching costs which decreases the bargaining power of suppliers in this industry.

3- Bargaining Power of Buyers:

As presented in table 5.1, the power of buyers in the Egyptian bottled water industry is high. As mentioned earlier, in the Egyptian bottled water industry, products are essentially the same. Since customers wouldn't incur any costs if they ceased buying from one brand and commenced buying from one of its competitors, the bargaining power of customers is likely to be higher.

4- Threats of Substitutes:

The threat of substitutes in the Egyptian bottled water industry is considered to be high. Although most bottled water consumers do not trust the quality or the healthiness of tap water or even filtered water, drinking tap water or filtered water is more cost effective than drinking bottled water which increases the threat of substitutes of bottled water.

5- Threat of New Entrants:

Table 5.1 shows that the threat of entry by new competitors in the Egyptian bottled water industry is low**.** At this time, there is no real threat of new entrants into the market. High start-up capital is required to operate in the Egyptian bottled water industry and this makes it less likely that new competitors will enter the market. A new entrant has to have access considerable finance to purchase the upfront capital, and then needs to have high volume of production to survive and high sales volumes to deliver a return on investment.

In addition, entering the Egyptian bottled water industry requires access to distribution channels. Since, it is not easy for new entrants to create distribution system, it is less likely that they will be able to enter and remain in the industry. Also, new entrants must overcome regulatory and legislative barriers before they can compete in the Egyptian bottled water market, which hinders new competitors entering the market.

The analysis in this section provided an overview of the current overall performance of the Egyptian bottled water sector including different brands and the market's major players. The Egyptian bottled water sector's general and competitive environment was described whereby the key factors influencing the market were analysed.

5.2.2 Screening case study nominations and developing the case study protocol

After studying and analysing the Egyptian bottled water market, case study nominations from this market were screened in order to select the most appropriate case to be conducted. Nine potential candidate companies were identified to serve as case studies in the application phase.

These nine companies represent the key players in the market (see figure 5.1). To select a candidate from this group qualified to serve as a case study in this research, the following criteria were defined:

1- The candidate should be a national brand. Selecting a national company to serve as a case study makes the study more relevant rather than selecting a multinational brand working in the Egyptian market.

2- The candidate should have been working in the Egyptian bottled water sector for not less than 5 Years.

3- The candidate should have a reasonable market share in both value and volume terms.

4- The candidate should be one of the brands that comply with set standards according to Trade Ministry investigations.

5- The candidate should have a detailed and accurate system for keeping data related to the company in all activities, which will ensure accuracy and facilitate the process of collecting data during the research phases.

6- The ability to access the company during different research phases.

Based on the previous criteria, an Egyptian natural bottled water company was selected to serve as a case study for this research. The name of the company will not be used for confidentiality reasons; therefore this research refers to the company as "the bottled water company". The bottled water company is a national brand that entered the market from more than 10 years. It uses an oracle system for keeping data related to most of its activities. According to the recent Trade Ministry investigation, the bottled water company has been judged to be one of the brands that comply with set standards. Also, it has been ranked as the fifth player in the market in terms of market share in 2009 (Memrb, 2010).

An introductory letter was submitted to the bottled water company as a request for the initial acceptance to gain access to it. Then a confidentiality agreement, also known as nondisclosure agreement (NDA), was prepared and signed to access to confidential data. The NDA terms protect against public disclosure of confidential information. According to this NDA, the real name of the company was not used in this study and the company's financial data were expressed in terms of percentage rather than values.

The case study protocol was developed to provide an overview of the case study project, data collection procedures, case study questions and a guide for the case study report. The detailed case study protocol is illustrated in Appendix 1.

The researcher scheduled regular visits to the company (3 days a week) over the case study duration. The implementation of the research procedure required the researcher to be embedded within the company. Detailed data from all departments in the company had to be collected on daily basis. In addition, in-depth observation was required in order to understand the day to day operations of the company's SC as well as the hierarchy of the whole SC processes from the top level to the implementations levels.

Primary data from the case study company were collected using both qualitative and quantitative primary data collection methods: the company's documentation, the company's archival records, direct casual observation, two key informants, two focus groups, unstructured interviews with key persons in the company, semi structured interviews with the managers of main departments and divisions and structured interviews with a group of experts from the company.

Table 5.2 summarises data collection procedures and case study questions that should be accomplished within different research phases; while detailed discussion of data collection procedures and methods in each phase will be presented in the next sections of this chapter.

Table 5.2: Data collection procedures and case study questions

Introductory phase		
Targeted output	**Data collection method/ model /technique**	**Case study questions**
Description of the Egyptian bottled water industry in terms of: different brands and the market's major players, the competitive environment and the key factors influencing the market.	1- Online references, periodicals and specialised journals	What are the Egyptian bottled water industry's features and characteristics?
Analysis of the overall performance of the Egyptian bottled water sector.	1- Online references, periodicals and specialised journals	What is the overall performance of the Egyptian bottled water sector?
An overview of the bottled water company through outlining briefly what the company does, how it developed historically, the company's current situation and the problems it is experiencing.	1- Documentation 2- Archival records 3- Direct observation (casual) 4- Interview (unstructured) 5- Informants 6- Online references	What does the bottled water company do, how it developed historically, what is the company's current situation and what problems it is experiencing?
Analysis of the characteristics, the structure and the strategy of the bottled water company's existing supply chain.	1- Documentation 2- Archival records 3- Direct observation (casual) 4- Interview (unstructured) 5- Informants 6- Online references, periodicals and specialised journals	What are the characteristics, the structure and the strategy of the bottled water company's existing supply chain?
Case study design		
Targeted output	**Data collection method/ model/ technique**	**Case study questions**
Mapping the main processes and sub processes of the bottled water company's supply chain based on the SCOR model standard description of SC processes.	1- Archival records 2- Direct observation (formal, casual) 3- Interview (semi-structured/focus group) 4- SCOR Model version 9 5- Informants	What are the main processes and sub processes of the bottled water company's supply chain?
Identification of the corresponding performance measures for the mapped processes based on the SCOR model standard performance metrics.	1- Documentation 2- Archival records 3- SCOR Model version 9 4- Informants	What are the corresponding performance measures for the main processes and sub processes of the bottled water company's supply chain?
Determination of the relative importance weights of the bottled water company's supply chain performance measurement attributes and sub-attributes.	1- Documentation 2- Archival records 3- Interview (formal survey) 4- Informants	What are the relative importance weights of the bottled water company's supply chain performance measurement attributes and sub-attributes?

Establishment of the performance rating scale for each of the supply chain performance measurement attributes and sub-attributes.	1- Documentation 2- Archival records 3- Focus group 4- Informants	What is the performance rating scale for each of the supply chain performance measurement attributes and sub-attributes?
Case study implementation and analysis		
Targeted output	**Data collection method/ model /technique**	**Case study questions**
Analysis of the current supply chain performance of the bottled water company's supply chain.	1- Documentation 2- Archival records 3- Informants	What is the current SCI of the bottled water company's supply chain?
Analysis of the current financial performance of the bottled water company.	1- Documentation 2- Archival records	What is the current SCFLI of the bottled water company?
Determination of the priorities of the bottled water company's financial performance objectives.	1- Documentation 2- Archival records 3- Interview (formal survey) 4- Informants 5- Financial performance metrics	What is the impact of the bottled water company's supply chain operations' performance on its overall financial performance?

5.3 Phase two: The introductory phase

An introductory phase about the bottled water company was conducted to outline briefly what the company does, how it developed historically, the company's current situation, the problems it is experiencing, the main members and the structural dimensions of its supply chain and its supply chain strategy.

Chapter two provided an insight into understanding and analysing the characteristics, the structure and the strategy of the targeted supply chain as a primary step to develop an effective SC performance measurement system (see section 2.4.1). Based on this review, the procedures for the analysis of the bottled water company's internal environment and existing SC were conducted and illustrated in this section.

This analysis was done based on data collected from the company's documentation, company's archival records, direct casual observation, unstructured interviews with key persons in the company and through on line references. In addition, two key informants were selected as a primary source of information: the Business Planning Manager and the Commercial Manager.

Informants were selected who had access to the information desired, had the willingness and the ability to communicate relevant knowledge and that were objective and unbiased. Moreover, at this phase, an introductory seminar was held to have all participants understand the basic concepts, terminologies and issues relevant to the research. The seminar details and agenda are illustrated in Appendix 2. Also the unstructured interview's protocol is included in the appendices (see Appendix 3.1).

The introductory phase mainly aimed to:

- develop an overview of the bottled water company business environment
- identify and analyse the characteristics, the structure and the strategy of the bottled water company's existing supply chain

5.3.1 An overview of the bottled water company business environment

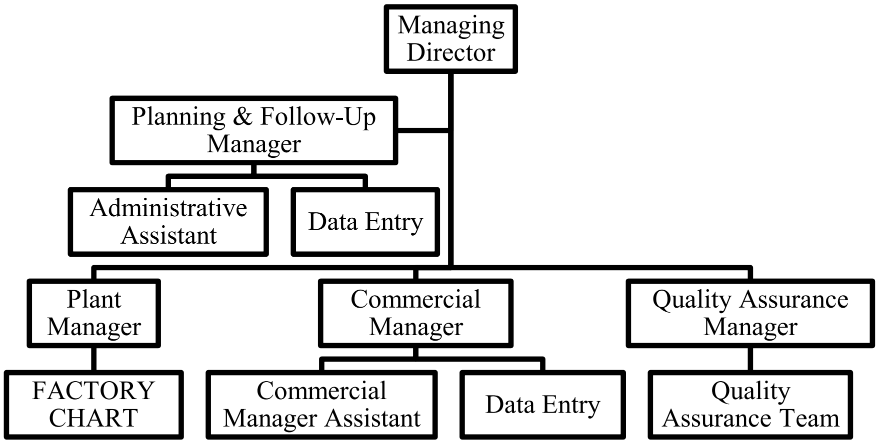
In this section, the company's profile is identified and its business environment is analysed. Based on this analysis, the company's strengths, weaknesses, opportunities and threats (SWOT) are identified.

The bottled water company is a manufacturing company specialising in the bottling and distribution of natural water. It is part of "a Group". The Group owns and/or operates major businesses in Egypt and North Africa including tens of successful businesses. The company objective is "*To serve the local economy by satisfying the needs of a diversified and growing customer base. It pursues this goal by supplying products that suit the customers' evolving requirements. An established, nationwide distribution network keeps it in close touch with the market and enables the company to maintain its commitment to customer.*"

The company follows a management by objective approach (MBO). It is a democratic management style where goals are determined by top and lower levels of the organisation together to form the goals system. MBO emphasises self-directing and self-control as a company's objectives become the action direction and motivation of each member, each level and each department. At the same time, these objectives become standards to check work performance in order to make sure that the company is effectively run (Liu, 2010). Applying an MBO management style helps the bottled water company's managers and employees to focus their efforts on activities that will lead to goal attainment and align their individual goals with the company's goals (Samson and Daft, 2011).

The bottled water company has a differentiation strategy. The company seeks to be unique in its industry along quality assurance that is widely valued by consumers. The bottled water company has a pure, healthy and deep source of water which is utilised to practice a differentiation strategy relying on offering pure and healthy bottled water. The company has a feedback controlling system which starts with setting goals and establishing standards of performance with respect to HACCP health and safety guidelines. Then, the actual performance is measured and compared to standard in order to take corrective actions.

The company has a traditional functional organisational structure. As shown in figure 5.4, the company's structure is characterised by high job specialisation and functional departments which enable employees to perform tasks within their specialised functional areas with a high level of speed and efficiency and to have clear career paths for hiring and promotion. However, the high level of specialisation makes coordination of activities between departments more difficult.



(Source: adapted from the case study company)

Figure 5.4: The bottled water company structure

Based on the analysis of the bottled water company's business environment and the Egyptian bottled water sector's general and competitive environmental analysis, the bottled water company's SWOT analysis was outlined in order to identify the strengths, weaknesses, opportunities and threats associated with the company's current situation. Figure 5.5 summarises the SWOT analysis of the bottled water company while the four elements of the company's SWOT analysis are discussed below in detail.

Strengths - Water source - Quality assurance - Providing the one-way family gallon - Expansion in foreign markets - Excellent leadership	**Weaknesses** -High transportation cost -High cost of water extraction - Limited control on marketing and distribution activities
Opportunities -Tap water pollution -The hot climate -The expansion of the retail infrastructure -The growing number of international visitors -Life style changes -Aggressive advertising	**Threats** -The adverse publicity generated by media campaigns -Advertising activities by key brands -Intense competition

Figure 5.5: The bottled water company SWOT analysis

1- Strengths:

- The bottled water company springs from the deep wells in the Western desert in Egypt which is considered the prime source of pure mineral water in Egypt as it is located 1000 kilometers away from all sources of pollution.
- The company applies a quality control system to ensure the quality of its operations. Also the company has been awarded ISO 9001:2000 certificate and HACCP certificate and gained a competitive advantage by being awarded ISO 2002 certificate in 2007.
- The bottled water company is the leading company in providing the one-way family gallon; it was the first company to provide this product to the Egyptian market since 1/8/2007. The company took the initiative to distribute this pack in the market for its advantages compared to other recycled packs. Also, it should be noted that the bottled water company provides some bottling companies with this pack that was produced with the cooperation of a Japanese company and an Egyptian company specialising in the plastic packs industry.
- The company has successfully expanded in foreign markets by exporting to England, the Ivory Coast, Kuwait and Palestine.
- The organisational structure and management style facilitate excellent managerial leadership where decision making occurs at the appropriate time and location.

2- Weaknesses:

- The transportation cost is high due to the long distance between the source of water at Siwa oasis, where the plant is located, and the market. Also the unpaved road between the source of water and the market contributes to high transportation cost.
- Water is drawn from a well of depth 1020 meters which makes the extraction cost relatively high compared to competitors.
- Being part of a Group, means that the bottled water company has limited control over some activities such as marketing and distribution as part of these activities are under the control of the parent company or other sister companies.

3- Opportunities:

- Tap water pollution drives the demand for bottled water in Egypt. The pollution of tap water in Egypt, which has increased the concerns about related illnesses such as stomach and kidney infections, is the main factor behind the growing demand for bottled water in Egypt (Euromonitor International, 2010).
- The Egyptian hot climate represents an opportunity as hot summers have increased the demand for bottled water in Egypt.
- The expansion of retail infrastructure in Egypt and the popularity of hypermarkets and shopping malls have created more space for restaurants and coffee shops.
- The growing number of international visitors has increased the demand for bottled water as they are keen to avoid the risk of stomach infections due to polluted tap water sources.

- Lifestyle changes are also changing drinking habits and making bottled water more attractive to Egyptian consumers.
- Advertising in this sector is aggressive and highly visible which helps to drive consumption.

4- Threats:

- The bottled water has suffered from the adverse publicity generated by media campaigns, as the government has tried to satisfy public concerns over the safety of tap water, which had a negative impact on the credibility of brands.
- Advertising activities by key brands such as Nestla Pure Life and Aquafina (Pepsi-Cola Egypt) were ongoing in 2008 and 2009. The campaigns are intending to restore consumers' confidence in these brands and to maintain brand equity.
- Intense competition especially from leader players: Aquafina, Nestla Pure Life and Dasani.

The previous analysis provided an overview of the bottled water company's profile and its business environment. The next stage would be identifying and analysing the characteristics, the structure and the strategy of the bottled water company's existing supply chain.

5.3.2 An overview of the bottled water company's existing supply chain

This section provides an overview of the bottled water company's existing SC through identifying the main members in the SC, analysing the structural dimensions of the SC, determining SC structural classification, mapping the geographical dispersion of the SC and identifying SC strategy. A detailed discussion of these procedures is presented below.

The main members in the supply chain

Four primary members were identified:

1- Raw material suppliers

The raw material suppliers are classified into two main groups: direct material suppliers and indirect material suppliers. The direct material suppliers group includes suppliers who supply components (bottle, cap, label, carton, shrink wrap and sleeve), while the indirect material suppliers group includes suppliers who supply chemicals, machines and spare parts.

2- Production

The production processes are undertaken by the bottled water company which represents the focal company in this supply chain.

3- Distribution

There is only one distributor (wholesaler) for all geographical areas, which is a sister company of the bottled water company.

4- Consumption

The end user in this supply chain is the bottled water customer in terms of retail channels to which the wholesaler sell the company's products. The bottled water company produces five different sizes of bottled water: 0.75, 1.5, 6, 12 and 19 litres.

The structural dimensions of the supply chain

1- The horizontal structure:

The bottled water company's supply chain has one tier of suppliers and two tiers of customers.

2- The vertical structure:

The vertical structure for direct raw material is narrow as the overall number of direct material suppliers are thirteen suppliers for the whole direct material. There is only one supplier for bottles, one supplier for caps, three suppliers for labels, two suppliers for carton, three suppliers for shrink wrap and three suppliers for sleeves.

On the other hand, the vertical structure for indirect material is relatively wide. Although only four suppliers are available for machines, the supply chain includes hundreds of suppliers of spare parts and chemicals.

Tier one customer includes only one distributor which is responsible for the distribution to Cairo, Alexandria, Sharm, Tanta, Matrouh and Gurgada; thus the vertical structure for tier one customer is narrow, while the end user tier is wide especially for .75 and 1.5 litres bottles.

The main members and the structural dimensions of the bottled water company's supply chain are illustrated in figure 5.6. It should be noted that the research focus is from tier 1 supplier through to tier 1 customer. Since it would be very difficult to trace tier 2 customer, tier 2 customer (end user) was excluded from the case study.

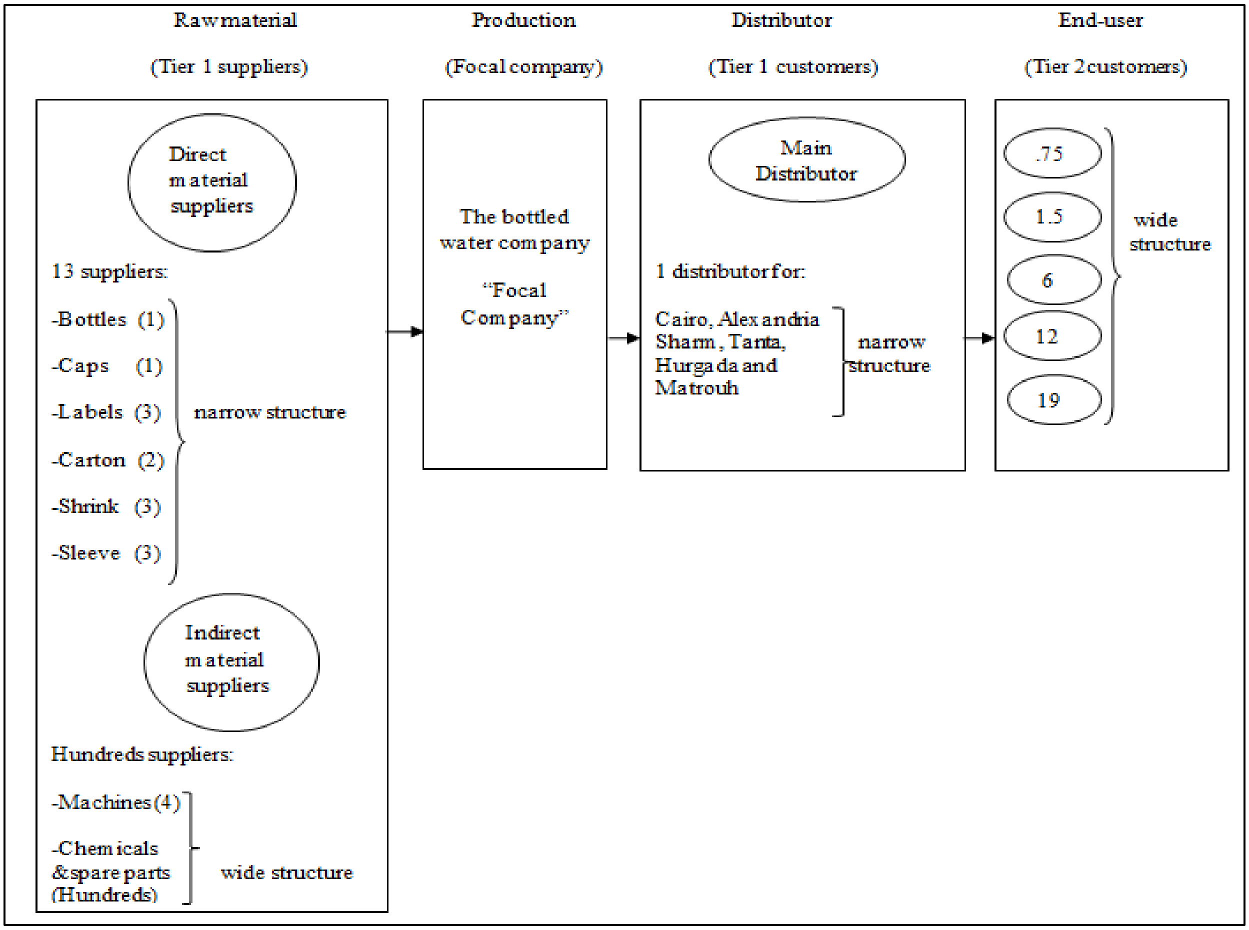


Figure 5.6: The main members and the structural dimensions of the bottled water company's supply chain

Supply chain structural classification

The bottled water company's supply chain structure is a convergent (assembly) type structure in which each node (or facility) in the chain has at most one successor, but may have any number of predecessors. Figure 5.7 presents the bottled water company's supply chain structure type.

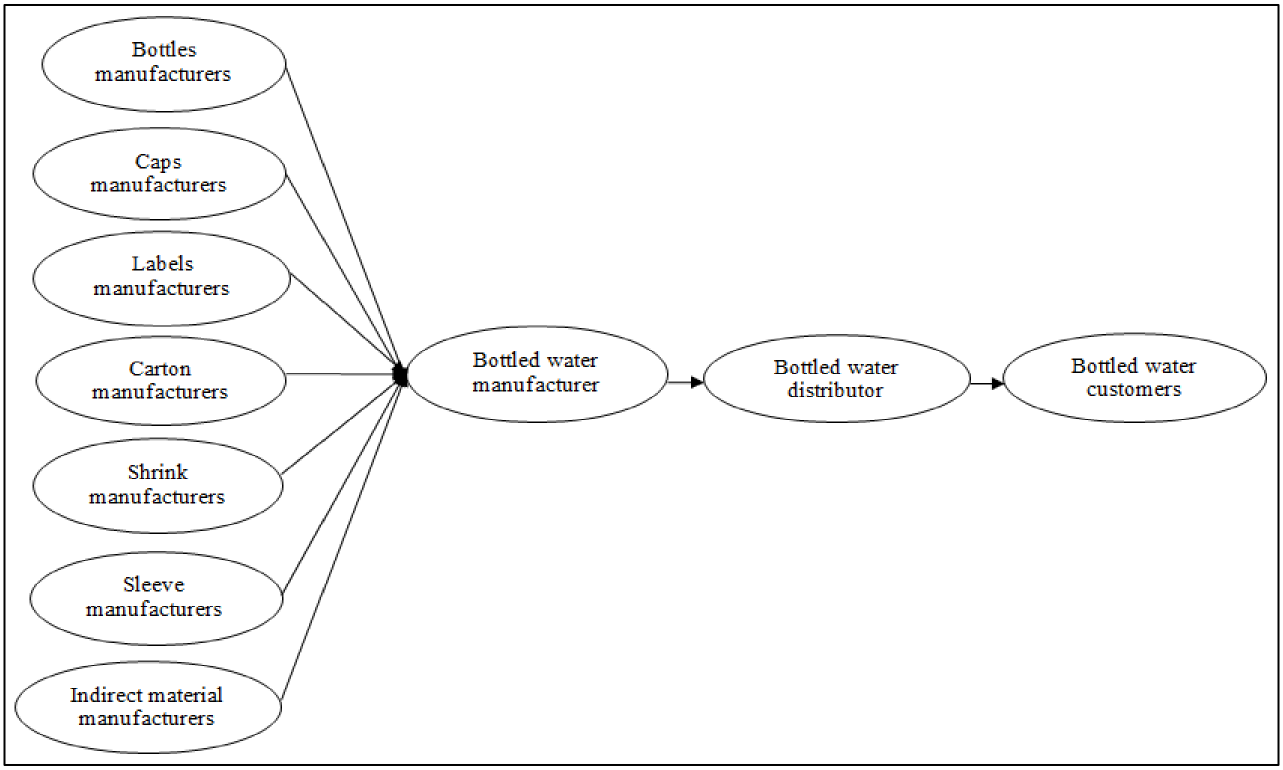


Figure 5.7: The bottled water company's SC structural classification

<u>Mapping the geographical dispersion of the supply chain</u>

The bottled water company's supply chain has a wide geographic dispersion. The geographic scope of the locations of suppliers, production facilities, distribution areas and customers are widely dispersed in seven geographical locations: Siwa, Alexandria, Cairo, Tanta, Sharm, Gardaga and Matrouh.

The focal company, the bottled water company, has two locations. The main location is the location of the plant in Siwa, while the administration building is in Alexandria.

All the direct material suppliers are concentrated in "Cairo" except the bottles supplier who has a location in Siwa near to the plant.

The indirect material suppliers for chemicals and spare parts are concentrated in "Alexandria" near to the administration building of the focal company, while the suppliers of the machines and spare parts are in Cairo.

The distributor is located in Alexandria and has warehouses in Cairo, Tanta, Gardaga, Matrouh and Sharm in order to distribute to end consumers in these areas. Figure 5.8 maps the geographical dispersion of the bottled water company's supply chain.

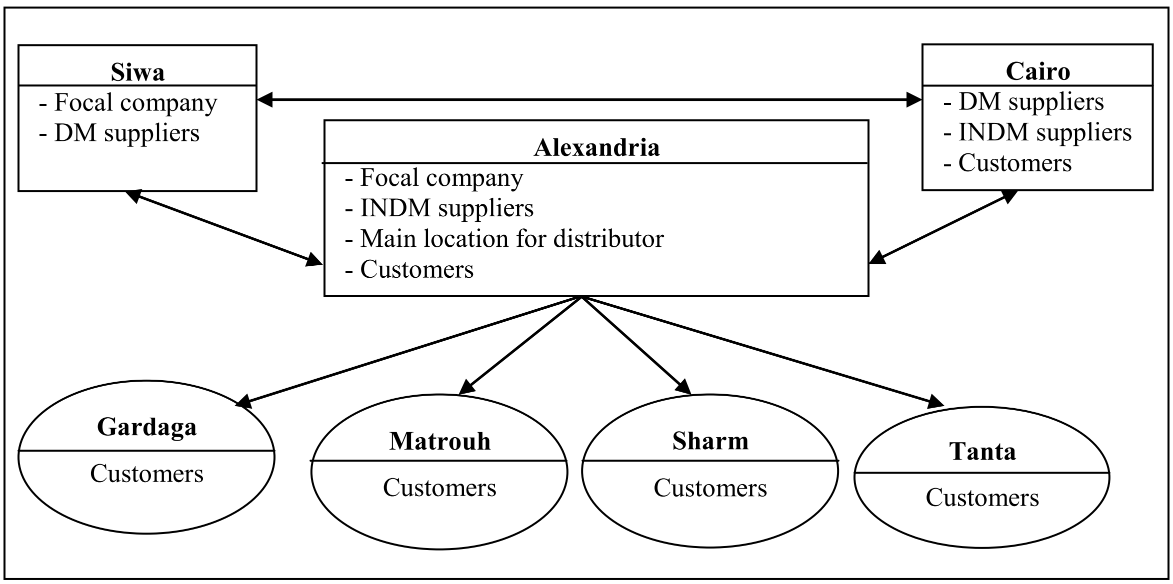


Figure 5.8: Geographical dispersion of the bottled water company's supply chain

Supply chain strategy

The bottled water company's supply chain has a build to stock strategy aiming at enhancing process efficiency in order to generate the greatest outcome from the least input through the minimisation of waste.

In summary, the previous analysis illustrated that the bottled water company's supply chain has four main members: raw material suppliers, production, distribution and consumption which represent one tier of suppliers and two tiers of customers. The vertical structure for direct raw material is narrow while the vertical structure for indirect material is relatively wide. The vertical structure for tier one customer is quite narrow while the end user tier is wide. The company has convergent (assembly) type supply chain structure with a wide geographic dispersion in seven geographical locations “Siwa, Alexandria, Cairo, Tanta, Sharm, Gardaga and Matrouh”. In addition, the bottled water company has “build to stock” strategy which requires developing and redesigning processes in order to remove over burden and eliminate waste.

5.4 Phase three: Establishing the SCOR FAHP technique

In this phase, the developed SCOR FAHP technique was established in the bottled water company, following the framework formulated in chapter four (see section 4.2), through:

1. Identifying the main processes and sub processes of the bottled water company’s SC, then mapping these processes to the SCOR model’s standard descriptions of SC processes
2. Identifying the corresponding performance measurement attributes for the previously mapped processes
3. Prioritising the importance of the supply chain performance measurement attributes
4. Establishing a performance rating scale for SC performance measurement attributes

5.4.1 Mapping the bottled water company’s SC processes to SCOR model’s standard descriptions of SC processes

Collecting data at this stage was through archival records, direct observation (formal, casual), interview (semi-structured/focused group) and informants. The main processes and sub processes for the bottled water company’s SC were mapped by executing the following steps:

Identifying the main processes and sub processes of the bottled water company's supply chain

An overview of the processes under examination was obtained through observing the process in operation and talking to the staff involved questioning how the work gets done. In addition, archival records from the company's databases were studied including:

- Organisation chart
- Job descriptions
- ISO procedures
- Illustration of the stages of water treatment, sterilisation, and sealing in bottles
- Illustration of the executed stages of quality assurance and quality control inside the factory, Water treatment, sterilisation, and sealing process flow chart
- Relationship map between core process and quality control
- Plan of recalling defective product

Semi-structured interviews were conducted with the managers of the main departments and divisions in the company: business planning department, commercial department, quality assurance department, production division, engineering division and warehousing division (see Appendix 3.2). For each department and division, those who are responsible for the process, the suppliers to the processes, the customers of the processes, the supervisors and the managers of the processes were identified. The following questions were asked at various steps in the process:

- What are the inputs to the processes under consideration?
- Where does your work come from?

- What do you do with it?
- Where do you send your output?
- What form does that output take?

After the data was collected from different sources, a flowchart initially was drawn to represent the process (without too much detail) by describing the sequence of tasks and decision points as they actually happen. The chart indicated:

- Who does what (Job title/Function),
- What is done and when,
- What decisions have to be taken , and
- What possible paths follow from each decision?

To ensure that the initial flow chart was drawn accurately, a focus group was assembled comprising representatives from all departments, who have good knowledge and understanding of the processes under examination. The departments and divisions' managers were not included in the focus groups since their participation would have skewed and reduced the free interaction of the focus group discussions. The initial flowchart was reviewed by the focus group to ensure that the processes were correctly identified and linked. The focus group was conducted in a semi-structured interview format, while its protocol is illustrated in Appendix 4.1. The following short list of open-ended questions was asked and the group discussed each question, in sequence:

- What do you think about this flowchart?
- Does this flow chart clearly identify the main processes and sub processes in your company?
- Does this flow chart correctly reflect the links between main processes and sub processes in your company?
- Do you think that there are any changes or modifications required to this flowchart?

<u>Mapping SC processes to SCOR model's standard descriptions of SC processes</u>

The bottled water company's SC processes were mapped to SCOR model version 9. The SCOR model version 9 was the latest available version when this study started. Two versions have been issued after version 9 (SCOR model version 10 and SCOR model version 11); however the minor changes between version 9 and the more recent versions do not affect the reliability of the model. Based on the SCOR model's standard description of SC processes, the bottled water company's SC processes were mapped. First, the company's SC processes were classified into five hierarchical levels: top level, configuration level, process element level and two process implementation levels. Then, these processes were mapped to the SCOR model standard process IDs and a new flowchart was created with these standardised processes. Finally, the description of the workflows was added to the chart in order to reflect the inputs and the outputs of the processes.

To ensure that the processes were correctly standardised and mapped to the SCOR model, the mapping of the main processes and sub processes of the bottled water company's supply chain was reviewed by the informants. Table 5.3 illustrates the mapping of the bottled water company's supply chain processes at the top level (level 1) and the configuration level (level 2).

Also, it presents the mapping of the source processes at the process-element level (level 3) as an example of processes mapping at this level. The full mapping of the bottled water company's supply chain processes at the process-element level and the implementation levels (levels 4, 5) are illustrated in Appendix 5. For each process, process's code, name, explanation, inputs, outputs and responsible department for this process have been identified.

Table 5.3: The bottled water company's supply chain processes mapping

Top level		
Process Code	Process Name	Definition
P	Plan	Processes that balance aggregate demand and supply to develop a course of action which best meets sourcing, production and delivery requirements.
S	Source	Processes that procure goods and services to meet planned or actual demand.
M	Make	Processes that transform product to a finished state to meet planned or actual demand.
D	Deliver	Processes that provide finished goods and services to meet planned or actual demand, typically including order management, transportation management, and distribution management.
SR	Source Return	Processes associated with returning products for any reason. These processes extend into post-delivery customer support.
DR	Deliver Return	Processes associated with receiving returned products for any reason. These processes extend into post-delivery customer support.
Configuration level		
Process Code	Process Name	Definition
P1	Plan Supply Chain	The development and establishment of courses of action over specified time periods that represent a projected appropriation of supply chain resources to meet supply chain requirements for the longest time fence constraints of supply resources.
P2	Plan Source	The development and establishment of courses of action over specified time periods that represent a projected appropriation of material resources to meet supply chain requirements.
P3	Plan Make	The development and establishment of courses of action over specified time periods that represent a projected appropriation of production resources to meet production requirements.
P4	Plan Deliver	The development and establishment of courses of action over specified time periods that represent a projected appropriation of delivery resources to meet delivery requirements.
P5	Plan Return	A strategic or tactical process to establish and adjust courses of action or tasks over specified time periods that represent a projected appropriation of return resources and assets to meet anticipated as well as unanticipated return requirements. The scope includes unplanned returns of sold merchandise as well as planned returns of "rotable" products that are refurbished for reissue to customers.
S1	Source Stocked Product	The procurement, delivery, receipt and transfer of raw material items, subassemblies, product and or services.
M1	Make-to-Stock	The process of manufacturing in a make to stock environment adds value to products through mixing, separating, forming, machining, and chemical processes. Make to stock products are intended to be shipped from finished goods or "off the shelf," are completed prior to receipt of a customer order, and are generally produced in accordance with a sales forecast.
D1	Deliver Stocked Product	The process of delivering product that is maintained in a finished goods state prior to the receipt of a firm customer order.
SR1	Source Return Defective Product	The process, initiated by the customer, of returning material deemed defective to the last known holder or designated return centre. Process includes: customer identification that an action is required and determining what that action should be, communicating with the last known holder, generating return documentation, and physical return of the product.

DR1	Deliver Return Defective Product	The processes of the last known holder or designated return centre authorizing and scheduling the defective product return and the physical receipt of the item by the last known holder or return centre and their transfer of the item for final disposition determination. The process includes communication between the customer and last known holder or known return centre and the generation of associated documentation.			
Process -Element level					
Process Code	Process Name	Definition	Process Inputs	Process Outputs	Responsible Department
S1-1	Schedule Product Deliveries	Scheduling and managing the execution of the individual deliveries of product against an existing contract or purchase order. The requirements for product releases are determined based on the detailed sourcing plan or other types of product pull signals.	Production schedule from M1-1/M1-2/ D1-3/P2-4 /Supplier performance/ Logistics selection	Work flow to S1-2/ P2-2/M1-1/ Supply Order Document	Commercial department for DM with assistance of Warehousing department/ Follow-up department for INDM with assistance of Warehousing department and engineering department
S1-2	Receive Product	The process and associated activities of receiving product to contract requirements.	Product from source/S1-1/ DR1-4 /Supply Order Document	Work flow to S1-3	Warehousing department/ The keeper of Material warehouse (for DM) / The keeper of Spare parts warehouse (for INDM)
S1-3	Verify Product	The process and actions required determining product conformance to requirements and criteria.	S1-2	Work flow to S1-4/ SR1-1 /Supplier performance/ Verification and Inspection report/ Adding material document/ Returns material document	Warehousing department and Quality department(for DM inspection) / Warehousing department and Engineering department (For INDM inspection)
S1-4	Transfer Product	The transfer of accepted product to the appropriate stocking location within the supply chain. This includes all of the activities associated with repackaging, staging, transferring and stocking product. For service this is the transfer or application of service to the final customer or end user.	S1-3/Inventory location/ D1-3/ Adding material document from S1-3	Work flow to S1-4/ SR1-1/ Supplier performance	Warehousing department/ The keeper of Material warehouse (for DM)/ The keeper of Spare parts warehouse (for INDM)
S1-5	Authorize Supplier Payment	The process of authorizing payments and paying suppliers for product or services. This process includes invoice collection, invoice matching and the issuance of checks.	S1-3/ S1-4/Payment terms/ SR1-5	…………………… …..	Financial department (with the assistance of Commercial department for DM and Follow-up department for INDM)

(Adopted from: SCOR Model - Version 9, Supply Chain Council, 2008)

5.4.2 Identifying the corresponding performance measurement attributes for the previously mapped processes

Collecting data at this stage was through documentation and archival records. The bottled water company’s objectives in 2009 and 2010 were studied. In addition, archival records from the company's databases were analysed including: Job descriptions, Performance appraisal forms (the management performance appraisal form and the employee performance appraisal form), Organisation objectives and departmental objectives, ISO procedures, Illustration of the executed stages of quality assurance and quality control inside the factory and Relationship map between core processes and quality control.

Based on the standard performance metrics of the SCOR model, the corresponding performance measurement attributes and sub attributes for the previously mapped processes were identified and then reviewed by the informants in order to ensure that they were correctly identified. Consequently, the hierarchical framework for the bottled water company’s SC performance measurement attributes was established. Table 5.4 illustrates the bottled water company’s level 1 SC performance metrics. SC performance metrics at lower levels (from level 2 metrics through to level 5 metrics) are presented in Appendix 6 including full details of SC performance measurement attributes (performance attribute code, name, definition and calculation and SC processes to which the performance attribute corresponds).

Table 5.4: The bottled water company's level 1 SC performance metrics

Performance Attribute Code	Performance Attribute Name	Definition	Calculation	Process	Performance Attributes				
					Customer-Facing			Internal-Facing	
					Reliability	Responsiveness	Agility	Cost	Assets
RL.1.1	Perfect Order Fulfilment	The percentage of orders meeting delivery performance with complete and accurate documentation and no delivery damage. Components include all items and quantities on-time using the customer's definition of on-time, and documentation - packing slips, bills of lading, invoices, etc.	[Total Perfect Orders] / [Total Number of Orders] x 100%	S1,M1,D1, SR1,DR1	✓				
RL.1.2	Forecast Accuracy	Forecast accuracy is calculated for products for markets/ distribution channels, in unit measurement.	(Sum Actuals - Sum of Variance)/ Sum Actuals to determine percentage error.	P	✓				
RS.1.1	Order Fulfilment Cycle Time	The average actual cycle time consistently achieved to fulfil customer orders.	[Sum Actual Cycle Times For All Orders Delivered] / [Total Number Of Orders Delivered] Order Fulfilment Cycle Time ≈ Source Cycle Time + Make Cycle Time + Deliver Cycle Time	S1, M1, D1		✓			
RS.1.2	Return Cycle Time	The average actual cycle time consistently achieved to receive returned products or return products for any reason.	[Sum Actual Cycle Times For All Orders Returned] / [Total Number Of Orders Returned] Order Return Cycle Time ≈ Source Return Cycle Time + Deliver Return Cycle Time	SR1, DR1		✓			

AG.1.1	Upside Supply Chain Flexibility	The number of days required to achieve an unplanned sustainable 20% increase in quantities delivered.	Total elapsed days between the occurrence of the unplanned event and the achievement of sustained plan, source, make, deliver and return performance. Note: Elapsed days are not necessarily the sum of days required for all activities as some may occur simultaneously.	S1,M1, D1, SR1,DR1			✓		
AG.1.2	Upside Supply Chain Adaptability	The maximum sustainable percentage increase in quantity delivered that can be achieved in 30 days.	Upside Source Adaptability + Upside Make Adaptability + Upside Deliver Adaptability	S1,M1,D1 ,SR1,DR1			✓		
AG.1.3	Downside Supply Chain Adaptability	The reduction in quantities ordered sustainable at 30 days prior to delivery with no inventory or cost penalties.	Downside Source Adaptability + Downside Make Adaptability + Downside Deliver Adaptability.	S1,M1, D1			✓		
CO.1.1	Supply Chain Management Cost	The sum of the costs associated with the SCOR Level 2 processes to Plan, Source, Deliver, and Return.	TSCMC = Sales – Profits – Cost to Serve (e.g., marketing, selling, administrative) TSCMC = Cost to Plan + Source + Deliver + Return Cost of Raw Material and Make Costs are not included here as generally they are accounted for in COGS. It is recognized that there is likely to be overlap/ redundancy between supply chain management costs and COGS if Make costs included here.	P1,P2, P3,P4, P5,S1, D1,SR1 ,DR1				✓	
CO.1.2	Cost of Goods Sold	The cost associated with buying raw materials and producing finished goods. This cost includes direct costs (labour, materials) and indirect costs (overhead).	COGS = direct material costs + direct labour costs + indirect costs related to making product	M1				✓	

AM.1.1	Cash-to-Cash Cycle Time	The time it takes for an investment made to flow back into a company after it has been spent for raw materials. For services, this represents the time from the point where a company pays for the resources consumed in the performance of a service to the time that the company received payment from the customer for those services.	[Inventory Days of Supply + Days Sales Outstanding – Days Payable Outstanding]	P1, P2, P3, P4, S1, M1, D1					✓
AM.1.2	Return on Supply Chain Fixed Assets	Return on Supply Chain Fixed Assets measures the return an organization receives on its invested capital in supply chain fixed assets. This includes the fixed assets used in Plan, Source, Make, Deliver, and Return.	Return on Supply Chain Fixed Assets = (Supply Chain Revenue – COGS – Supply Chain Management Costs) /Supply-Chain Fixed Assets	P1, P2, P3, P4, S1, M1, D1, SR1, DR1					✓
AM.1.3	Return on Working Capital	Return on working capital is a measurement which assesses the magnitude of investment relative to a company's working capital position verses the revenue generated from a supply chain. Components include accounts receivable, accounts payable, inventory, supply chain revenue, cost of goods sold and supply chain management costs.	Return on Working Capital = (Supply Chain Revenue – COGS – Supply Chain Management Costs) / (Inventory +Accounts Receivable – Accounts Payable)	P1, P2, P3, P4, S1, M1, D1, SR1, DR1					✓
AM.1.4	Capacity Utilization	A measure of how intensively a resource is being used to produce a good or service.	Some factors that should be considered are internal manufacturing capacity, constraining processes, direct labour availability and key components availability.	M1.1, M1.3, M1.4					✓

(Adopted from: SCOR Model - Version 9, Supply Chain Council, 2008)

5.4.3 Prioritising the importance of the supply chain performance measurement attributes

To determine the relative importance weights of SC performance attributes at different hierarchal levels, the following steps were executed based on the procedures illustrated in section 4.2.

Administering the FAHP questionnaire to the selected expert group

A group of four experts was assembled following the criteria specified in chapter four (see section 4.2). The group comprised: business planning manager, commercial manager, quality assurance manager and engineering division manager.

Structured interviews were conducted with the expert group in order to determine the relative importance weights of SC performance attributes at different hierarchical levels (see Appendix 3.3). In the interviews, a pair-wise questionnaire was used to facilitate comparison of sub attributes. The questionnaire form is presented in figure 5.9.

According to this questionnaire, the relative importance of two elements was rated using a scale with the values 1, 3, 5, 7 and 9, where 1 denotes equally important, 3 for slightly more important, 5 for strongly more important, 7 for demonstrably more important and 9 for absolutely more important. Using this questionnaire, the group of experts was asked to determine the relative weights of sub attributes at different levels from implementation levels up to configuration level.

For this survey, 52 metrics including 153 pairs of comparison were established. In this phase, the expert group wasn't asked to assign the relative importance weights for the main supply chain performance measures at the top level (RL, RS, AG, CO, AM), with the main five performance measures having equal weight in the aggregation procedure (20%) in this phase.

The relative importance weights for these measures are determined in a later phase with respect to the financial performance priorities in order to calculate SCFLI.

With respect to (……..)	Importance or preference of one main (sub) attribute over another									
Attribute	Absolutely more important **(9)**	Demonstrably more important **(7)**	strongly more important **(5)**	Slightly more Important **(3)**	Equally important **(1)**	Slightly more Important **(3)**	strongly more important **(5)**	Demonstrably more important **(7)**	Absolutely more important **(9)**	**Attribute**
C1										C2
………										……..
Cn-1										Cn

Figure 5.9: Questionnaire form to facilitate comparison of SC performance measurement attributes

Establishment of the aggregate pair-wise comparison matrix

To aggregate the experts' responses, a fuzzy pair-wise comparison matrix based on triangular fuzzy numbers (L, M, U) was used in expressing the consolidated opinions of the experts. For the questionnaire responses, $\alpha = 0.5$ was used to express that environmental uncertainty was steady; in addition, $\lambda = 0.5$ was used to express that a future attitude was fair.

To establish the aggregate pair-wise comparison matrix, defuzzification of the triangular fuzzy numbers derived from the fuzzy pair-wise comparison matrix was performed; consequently the aggregate pair-wise comparison matrix was established and the Eigenvector method was used for weight calculation. The Consistency Index (CI) and the Consistency Ratio (CR) were calculated for each aggregate pair-wise comparison matrix at each level in order to verify the consistency of the comparison matrix.

Finally, the relative weights of the SC performance measurement attributes were determined by aggregating the weights throughout the hierarchy. Table 5.5 summarises the relative weights of the bottled water company's SC performance measurement attributes at level 1 metrics. The relative weights of the SC performance attributes at different levels and the detailed measurement procedures to determine their relative weights are included in Appendix 7.

Table 5.5: the relative importance weights of the bottled water company's SC performance measures at level 1 metrics

Attribute name	Attribute code	Eigen vector (weight)
Supply Chain Reliability	**RL**	
Perfect Order Fulfilment	RL1-1	35.7%
Forecast Accuracy	RL1-2	64.3%
Supply Chain Responsiveness	**RS**	
Order Fulfilment Cycle Time	RS1-1	82.7%
Return Cycle Time	RS1-2	17.3%
Supply Chain Agility	**AG**	
Upside Supply Chain Flexibility	AG1-1	28.3%
Upside Supply Chain Adaptability	AG1-2	53.0%
Downside Supply Chain Adaptability	AG1-3	18.7%
Supply Chain Costs	**CO**	
Supply Chain Management Cost	CO1-1	33.1%
Cost of Goods Sold	CO1-2	66.9%
Supply Chain Asset Management	**AM**	
Cash-to-Cash Cycle Time	AM1-1	44.2%
Return on Supply Chain Fixed Assets	AM1-2	11.9%
Return on Working Capital	AM1-3	17.5%
Capacity Utilization	AM1-4	26.4%

5.4.4 Establishing a performance rating scale for SC performance measurement attributes

At this stage, a five point performance rating scale (very poor, poor, good, very good and excellent) was established for the leaf nodes of the bottled water company's SC performance measures to be used as a benchmark in order to assess the performance of supply chain operations. The leaf nodes are performance measures at the lowest levels in the SCOR hierarchy which are not aggregated from sub performance measures. Collecting data for this stage was through the company's documentation and archival records and focus group interviews. In order to establish the performance rating scale, the following steps were executed:

- The leaf nodes SC performance measures were classified into two groups: newly developed measures that would be applied for the first time in the company and existing measures that were already applied in the company.
- For the existing measures, the historical performance of the company for each measure was compiled for the last five years. Based on this historical performance data, a five point performance rating scale for the existing measures was established whereby the minimum historical performance represented very poor performance in the scale while the excellent performance in the scale was calculated based on the targeted percentage increase above the maximum historical performance.
- A focus group comprising the selected group of experts (i.e. business planning manager, commercial manager, quality assurance manager and engineering division manager) was carried out in a semi-structured interview format (see Appendix 4.2). The focus group was asked to determine the targeted percentage increase above the maximum historical performance taking into consideration the company's business environment, current situation, strategies and goals.
- Since there is no historical data available in the company for the newly developed measures, the focus group was asked to set a minimum and a maximum expected performance for each newly developed measure taking into consideration the company's business environment, current situation, strategies and goals. Based on these expectations, a five point performance rating scale for the newly developed measures was

established whereby the maximum expected performance represented excellent performance in the scale while the minimum expected performance represented very poor performance in the scale.

- To ensure construct validity, the established performance rating scale for both the existing measures and the newly developed measures was reviewed and agreed by the informants.
- Using the established performance rating scale, supply chain performance measurement attributes can be internally benchmarked. A performance rate (0.2, 0.4, 0.6, 0.8 or 1) can be assigned for each leaf node performance measurement attribute with respect to the performance rating scale in order to assess the company's day-to-day SC operations performance. Where 0.2 denotes very poor performance, 0.4 denotes poor performance, 0.6 denotes good performance, 0.8 denotes very good performance and 1 denotes excellent performance. As an example, table 5.6 illustrates the performance rating scale for SC costs measures, while the performance rating scale for all bottled water company's SC performance measurement attributes is illustrated in Appendix 8.

Table 5.6: The developed performance rating scale for the bottled water company's SC costs measures

Supply Chain Costs								
Performance Attribute Code	Performance Attribute Name	MIN	MAX	Performance rating scale				
				VP	P	G	VG	E
CO.2.1	Freight expense (% of total cost)	0.17	0.108	0.17	0.155	0.139	0.124	0.108
CO.2.2	Direct marketing expense (% of total cost)	0.08	0.036	0.08	0.069	0.058	0.047	0.036
CO.2.3	Direct sales expense (% of total cost)	0.2	0.153	0.2	0.188	0.177	0.165	0.153
CO.2.4	Administrative expense (% of total cost)	0.02	0.009	0.02	0.017	0.015	0.012	0.009
CO.3.1	M Cost (% of total manufacturing cost)	0.75	0.54	0.75	0.698	0.645	0.593	0.54

CO.3.2	L Cost (% of total manufacturing cost)	0.15	0.09	0.15	0.135	0.12	0.105	0.09
CO.3.3	Indirect Costs Related To Making Product (% of total manufacturing cost)	0.25	0.135	0.25	0.22	0.193	0.164	0.135

After determining the performance rate and the relative weight of each attribute, the weighted rate for each SC performance measurement attribute can be calculated as stated earlier in chapter four (see equation 13). The weighted rates of all performance measurement attributes are then aggregated throughout the hierarchy of SC performance measures to determine the company's supply chain performance index (SCI).

5.5 Phase four: Implementation phase

During the implementation phase, a software (SW) application system is designed to enable the real application of the developed research method through evaluating SC operations' performance and calculating the SCI. Then, the bottled water company's current financial performance is evaluated in order to determine the priorities of financial performance factors. Finally, according to these priorities, the relative importance weights of the five main SC performance measures are calculated. A detailed discussion of the implementation phase procedures is presented below.

5.5.1 Evaluating SC operations' performance and calculating SCI

A SW application utilising the SCOR FAHP technique, called 'Supply Chain Management Key Performance Indicators' (SCM KPIs) system was proposed. It is a software package designed by the researcher for the purpose of evaluating SC operations' performance and calculating the SCI.

To develop the SCM KPIs system, a Database Management System (DBMS) was required. A DBMS environment allows flexible representation and aggregation of raw data. It provides the ability to create tables to house data and establish links between tables offering easy access and maintenance of data observations and their relationships. In addition to numeric data manipulation, it allows parsing of textual strings for distinct word (types) and different occurrences of words (tokens) (Wolfram, 2006).

Since the researcher is not specialised in software development, the SCM KPIs system was designed by the researcher while it was further developed by *Tatweer For Information Technology*, a software development company. A Structured Query Language (SQL) database was used to develop the SCM KPIs system. SQL is a DBMS that gives the opportunity to view data in different ways through SQL data grouping. It is a standardised query language enabling the requesting of information from a database which facilitates data analysis from different perspectives.

The developed SCM KPIs consists of four main pages:

1- Home page: This page includes links to departments' data entry, processes details and performance measures details.

2- Management: This page includes links to SC performance rating scale and SC annual performance.

3- Dashboard: This page includes charts summarising and analysing the annual SC performance.

4- About: This page provides information about programme idea, the bottled water company, Huddersfield University and Tatweer For Information Technology, company by which this SW application is developed.

An overview of the SCM KPIs system and its tabs, screens and pages is illustrated in Appendix 9.

After establishing the SCOR FAHP technique (phase three), it took four months to design and develop the SCM KPIs system; followed by two months trial phase before the implementation. Implementation of the SCM KPIs system comprised four major stages namely:

- setting up the application in SQL;
- enabling the departments to enter daily SC operations data;
- aggregating SC operations annual performance and
- calculating SCI.

The application of the four steps to the case study company is illustrated in the following sections (Elgazzar et al., 2011b).

Setting up the application in SQL:

The bottled water company's SC processes map created in the third phase (see section 5.4.1) was inserted in the database including the details of each process (process's code, name, explanation, inputs, outputs and responsible department for this process). Using the SQL database, the bottled water company's SC processes can be grouped in order to illustrate data in different ways. Processes can be grouped based on process type, level of process hierarchy, the responsible department and the types of inputs or types of outputs. Figure 5.10 presents an example extracted from SCM KPIs system's processes map at process element level.

Process Code	Process Name	Definition	Process Inputs	Process Outputs	Responsible Department	
M						
M1.1	Schedule Production Activities	Given plans for the production of specific parts, products, or formulations in specified quantities and planned availability of required sourced products, the scheduling of the operations to be performed in accordance with these plans. Scheduling includes sequencing, and, depending on the factory layout, any standards for setup and run. In general, intermediate production activities are coordinated prior to the scheduling of the operations to be performed in producing a finished product.	Equipment and facilities schedule/S1-1 /P3-4	Work flow to M1-2 /S1-1/D1-3	Commercial department and Production department with assistance of Warehousing department	Edit
M1.2	Issue Material	The selection and physical movement of sourced/in-process product (e.g., raw materials, fabricated components, subassemblies, required ingredients or intermediate formulations) from a stocking location (e.g., stockroom, a location on the production floor, a supplier) to a specific point of use location. Issuing product includes the corresponding system transaction. The Bill of Materials/routing information or recipe/production instructions will determine the products to be issued to support the production operation(s).	M1-1/Inventory availability from S1-4/ Issuing material request document	Work flow to M1-3 /S1-1/ D1-3/P3-2/ Feed back to M1-1 /Issuing material document	The keeper of Direct Material warehouse	Edit
M1.3	Produce and Test	The series of activities performed upon sourced/in-process product to convert it from the raw or semi-finished state to a state of completion and greater value. The processes associated with the validation of product performance to ensure conformance to defined specifications and requirements.	M1-2/ Production standards	Work flow to M1-4/Feed back to M1-1	The production department and The Quality department	Edit

Figure 5.10: An example of SC processes' details at process element level

The corresponding SC performance measurement attributes from level 1 metrics through to level 5 metrics, which have been identified in section 5.4.2, were incorporated in the database along with their details (performance attribute code, name, definition and calculation and SC processes to which this performance attribute corresponds). The SQL database enables SC performance measures to be grouped and analysed based on different perspectives such as measure category (i.e. RL, RS, AG, CO or AM) and level in the hierarchy of performance measures.

Figure 5.11 presents an example of how SC performance measures' details are illustrated in the database. For example, AG2.1 refers to the performance attribute '*Upside Source Flexibilty*' which measures the number of days required to achieve an unplanned sustainable 20% increase in quantity of raw materials. The *Upside Source Flexibilty* evaluates the flexibility of SC source process (S1) in terms of the least time required to pursue all necessary activities related to source process.

Performance Attribute Code	Attribute Name	Arabic Attribute Name	Attribute Definition	Calculation	Process
AG 2.1	Upside Source Flexibility	مدى قدرة أنشطة التوريد للإستجابة لزيادة الطلب الغير متوقعة	The number of days required to achieve an unplanned sustainable 20% increase in quantity of raw materials.	Least time to pursue all necessary activities.	S1
AG 2.2	Upside Make Flexibility	مدى قدرة مراحل التصنيع للإستجابة لزيادة الطلب الغير متوقعة	The number of days required to achieve an unplanned sustainable 20% increase in production with the assumption of no raw material constraints.	Least time to pursue all necessary activities.	M1
AG 2.3	Upside Deliver Flexibility	مدى قدرة إستجابة المراحل اللازمة لتسليم المنتج للعميل للزيادة الغير متوقعة فى الطلب	The number of days required to achieve an unplanned sustainable 20% increase in quantity delivered with the assumption of no other constraints.	Least time to pursue all necessary activities.	D1

Figure 5.11: An example of SC performance measures' details at level 2 metrics

Also, the relative weights and the performance rating scale of the bottled water company's SC performance measures, which were illustrated in sections 5.4.3 and 5.4.4 respectively, were included in the database of SCM KPIs system (see figure 5.12).

As mentioned earlier in section 5.4.4, a performance rate can be assigned for each measure based on the established five point performance rating scale (very poor (VP), poor (P), good (G), very good (VG) and excellent (E)). Then, the weighted rates of all performance measures can be calculated and aggregated in order to determine the company's SCI. In addition, as illustrated in figure 5.13, the database enables editing the weights and the performance rating scale, which makes the system flexible to adapt to any changes.

Figure 5.12: The importance weights and the performance rating scale of SC performance measures

Figure 5.13: Editing the importance weights and the performance rating scale of SC performance measures

Enabling the departments to enter daily SC operations data

The leaf nodes of performance measures were classified according to the responsible department based on the description of the mapped SC processes. A data entry screen was designed for each department (commercial, engineering, financial, follow up, planning, production and quality) including the leaf nodes allocated to the department (see figure 5.14). Table 5.7 illustrates the department responsible for entering data into each screen and also identifies the time frequency for data entry.

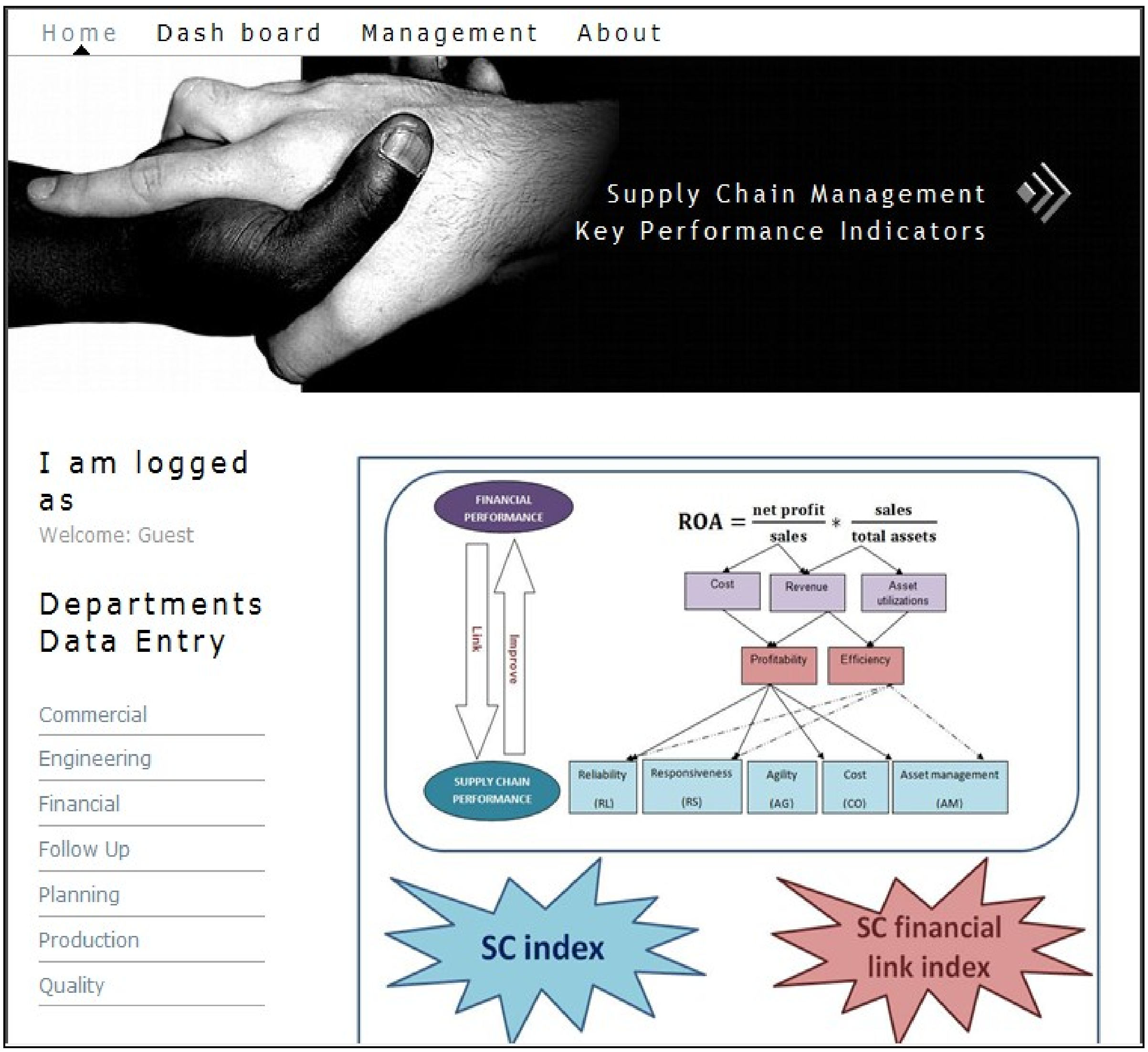


Figure 5.14: Departments' data entry screens

Table 5.7: Departments' data entry screens names and their time frequency

Screen name	Time frequency
COMMERCIAL	
Accuracy of month DM orders	Per order
Average cycle time of month DM orders+ Average cycle time of month source return orders	Per order
Accuracy of month source forecast+ Accuracy of month source return forecast	Per month
Source agility	Per month
Annual % of spoilage material	Per month
Monthly schedule delivers	Per month
FOLLOW UP	
Annual accuracy % of INDM orders	Per order
Annual average cycle time of INDM orders	Per order
Accuracy of month delivered orders	Per order
Average cycle time of month deliver orders+ Average cycle time of month deliver return orders	Per order
Accuracy of month deliver forecast+ Accuracy of month deliver return forecast	Per month
Deliver agility	Per month
PLANNING	
Annual accuracy % of INDM orders	Per order
Annual average cycle time of INDM orders	Per order
ISO documents accuracy	Per year
SC forecast accuracy	Per year
ENGINEERING	
Average % of month down time	Per day for each production line
Scheduled Equipment Downtime	Per month
FINANCIAL	
Yearly supply chain financial data	Per year
QUALITY	
Accuracy of month transferred orders	Per order
PRODUCTION	
Average make cycle time of month + Average % of month operating rate	Per shift for each production line
Make agility	Per month
Accuracy of month make forecast	Per month
Monthly schedule production	Per month

For each leaf node, the data for the corresponding SC processes was entered for the year ended December 31st 2010 on a daily or monthly basis according to the process. This data was then aggregated at the end of the year to establish an annual measure. Each department had a result sheet summarising the values of leaf node measures allocated to the department.

An example is illustrated in figure 5.15 for the commercial department to evaluate source agility. Data is entered for direct material (DM) orders agility (upside flexibility, upside adaptability and downside adaptability) on a monthly basis and then aggregated for the year to reflect the agility of DM orders. Samples of the departments' data entry and results sheets for the year ended December 31st 2010 are illustrated in Appendix 10.

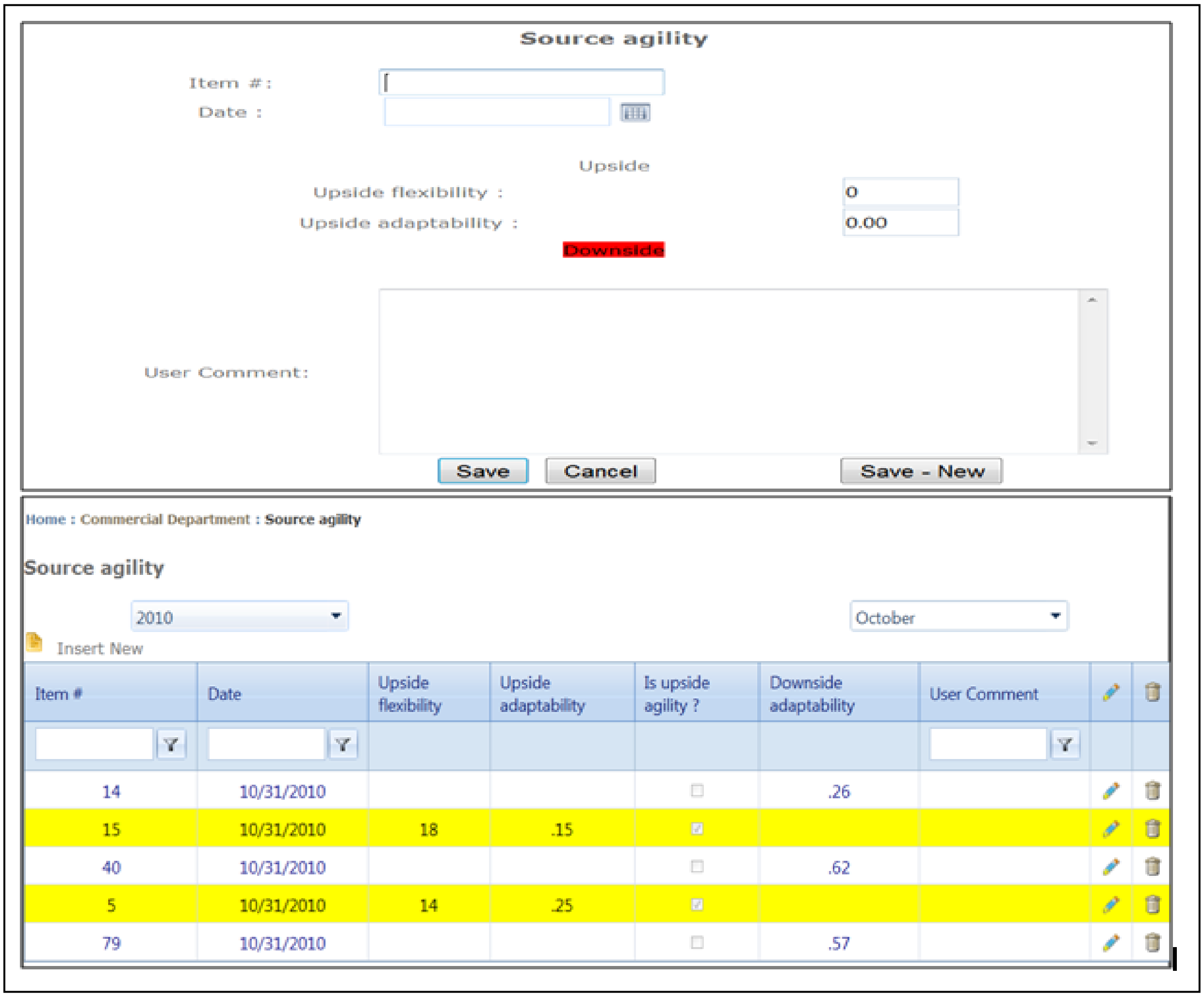


Figure 5.15: SC source agility

Aggregating SC operations annual performance:

Based on the annual value of each leaf node, a performance rate (0.2, 0.4, 0.6, 0.8 or 1) was assigned with respect to the performance rating scale. As explained earlier in section (4.2), the annual weighted rate of leaf nodes were calculated by multiplying the rate of each leaf node by its weight. The weighted rate of leaf nodes were aggregated throughout the hierarchy of SC performance measures in order to determine the performance index of the company's supply chain. The aggregated weighted rates of the bottled water company's SC performance measures for the year ended December 31st 2010 are presented in Appendix 11.

Figure 5.16 illustrates the aggregated performance of SC agility measures for the year ended December 31st 2010. A performance rate was assigned for each agility measure at level 2 metrics with respect to the performance rating scale. The weighted rate for each agility measure at level 2 metrics was calculated by multiplying the assigned rate by the measure's relative weight. The weighted rates of the agility measures at level 2 metrics are then aggregated in order to determine SC agility performance at level 1 metrics. For example, the weighted rates of AG 2.1, AG 2.2 and AG 2.3 were aggregated to determine the performance of the Upside Supply Chain Flexibility (AG 1.1). Finally, the weighted rates at level 1 metrics were aggregated to determine the overall SC agility performance. The overall performance rate of the bottled water company SC agility for the year ended December 31st 2010 was 0.64. This rate presented the aggregated weighted rates of SC agility measures at level 1 metrics (AG 1.1, AG 1.2 and AG 1.3).

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
Node : AG									
AG 1.1	Upside Supply Chain Flexibility	مرونة سلسلة الإمداد للإستجابة لزيادة الطلب الغير متوقعة	.2	1	.28		VP	.2	.056
AG 1.2	Upside Supply Chain Adaptability	مدى مرونة سلسلة الإمداد للإستجابة خلال فترة زمنية محددة لزيادة الغير متوقعة في الطلب	.2	1	.53		E	.874	.463
AG 1.3	Downside Supply Chain Adaptability	مرونة سلسلة الإمداد للإستجابة السريعة خلال أقل فترة زمنية ممكنة للنقص الغير متوقع في الطلب	.2	1	.19		VG	.608	.116
AG 2.1	Upside Source Flexibility	مدى قدرة أنشطة التوريد للإستجابة لزيادة الطلب الغير متوقعة	15	2	.33	15.717	VP	.2	.066
AG 2.2	Upside Make Flexibility	مدى قدرة مراحل التصنيع للإستجابة لزيادة الطلب الغير متوقعة	4	1	.4	4.333	VP	.2	.08
AG 2.3	Upside Deliver Flexibility	مدى قدرة إستجابة المراحل اللازمة لتسليم المنتج للعميل لزيادة الغير متوقعة في الطلب	3	1	.27	3.3	VP	.2	.054
AG 2.4	Upside Source Adaptability	مدى قدرة أنشطة التوريد للإستجابة خلال فترة زمنية محددة لزيادة الغير متوقعة في الطلب	.75	1	.35	.987	E	1	.35
AG 2.5	Upside Make Adaptability	مدى قدرة مراحل التصنيع للإستجابة خلال فترة زمنية محددة لزيادة الغير متوقعة في الطلب	.3	.7	.44	.675	E	1	.44
AG 2.6	Upside Deliver Adaptability	مدى قدرة إستجابة المراحل اللازمة لتسليم المنتج للعميل خلال فترة زمنية محددة لزيادة الغير متوقعة في الطلب	.15	.25	.21	.171	P	.4	.084
AG 2.7	Downside Source Adaptability	مدى قدرة أنشطة التوريد للإستجابة السريعة خلال أقل فترة زمنية ممكنة للنقص الغير متوقع في الطلب	.3	.6	.41	.527	E	1	.41
AG 2.8	Downside Make Adaptability	مدى قدرة مراحل التصنيع للإستجابة السريعة خلال أقل فترة زمنية ممكنة للنقص الغير متوقع في الطلب	.25	.3	.4	.257	P	.4	.16
AG 2.9	Downside Deliver Adaptability	مدى قدرة إستجابة مراحل تسليم المنتج للعميل للنقص الغير متوقع في الطلب وذلك خلال أقل فترة زمنية ممكنة	.25	.3	.19	.217	VP	.2	.038

Figure 5.16: The aggregated performance of SC agility measures for the year ended December 31st 2010

Calculating SC index:

As illustrated in figure 5.16, each SC performance measurement attribute had a weighted rate and corresponded to specific processes in the SC. Accordingly, the company can trace the contribution of each SC process to the overall SC performance in order to highlight processes which need improvement and identify their related performance indicators for improved SCM.

The overall aggregated performance of each SC performance measurement category (reliability, responsiveness, agility, costs and asset management) was determined by aggregating the weighted rates of SC performance measures that fall into each category throughout the hierarchy of SC performance measures (see figure 5.16). Then, the bottled water company's SCI was calculated by aggregating the performance of the five main SC performance measurement categories. As illustrated in table 5.8, equal weight (20%) was assigned to the five main SC performance measures. The company's SCI for the year ended December 31st 2010 was 0.56 (see equation 1). The index revealed that the company's SC performance in this period was good on average according to the interval based performance scale ([0.0<R<=0.2], [0.2<R<=0.4], [0.4<R<=0.6], [0.6<R<=0.8], [0.8<R<=1]) established in section 4.2; where R denotes value of the SCI, [0.0<R<=0.2] denotes very poor performance, [0.2<R<=0.4] denotes poor performance, [0.4<R<=0.6] denotes good performance, [0.6<R<=0.8] denotes very good performance and [0.8<R<=1] denotes excellent performance.

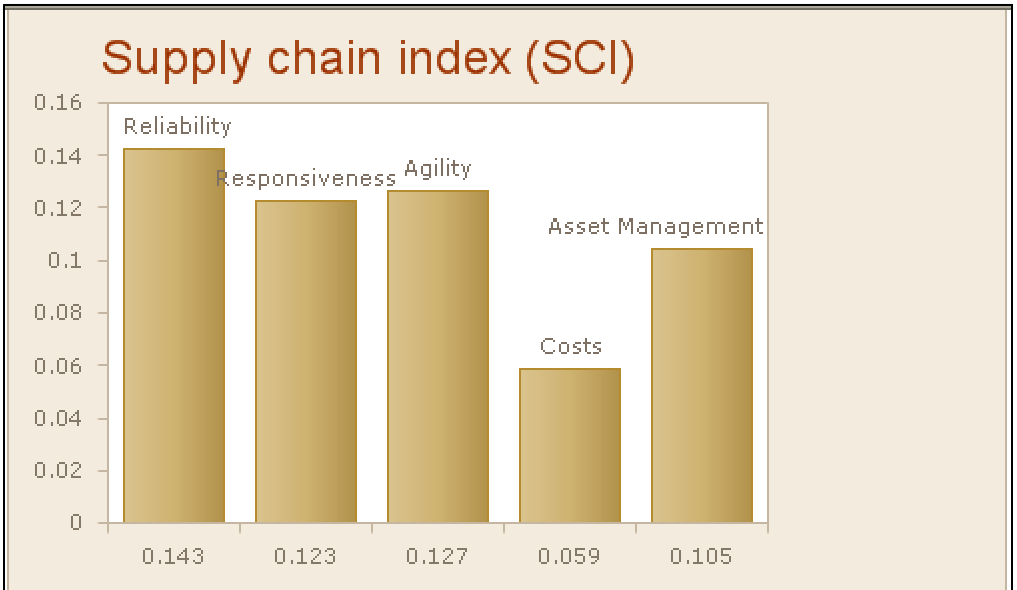
Table 5.8: Calculating SCI of the bottled water company for the year ended December 31st 2010

Measure	**SCI**			
	R	W	WR	Assessment rate
RL	0.72	20%	0.143	VG
RS	0.62	20%	0.123	VG
AG	0.64	20%	0.127	VG
CO	0.29	20%	0.059	P
AM	0.53	20%	0.105	G
SUM	2.8	100%	0.557	G

$$SC\ index\ (SCI) = \frac{\sum R}{N} = \frac{2.8}{5} = 0.56 \quad (1)$$

where N represents the number of the main SC performance measures.

As shown in table 5.8, according to the interval based performance scale, the performance of SC processes to which reliability, responsiveness and agility measures correspond was very good, the performance of SC processes to which asset management measures correspond was good; while the performance of SC processes to which costs measures correspond was poor. As presented in figure 5.17, the results were displayed in a dashboard summarising and analysing the annual SC performance for the year ended December 31st 2010.



Attribute Name	Weighted Rate
Reliability	.143
Responsiveness	.123
Agility	.127
Costs	.059
Asset Management	.105
SCI	.557

Figure 5.17: The bottled water company's SCI (2010)

5.5.2 Evaluating the company's current financial performance and determining the priorities of financial performance factors

The bottled water company's financial data for the year ended December 31st 2010 (period 1) was extracted from its financial statements. The Du Pont ratio for the company was calculated and compared to the industrial average. As illustrated in table 5.9, a negative return on asset ratio was registered by the company. To identify the factors behind this low performance, the Du Pont ratio was broken into its components (Net Profit Margin and Total Assets Turnover) reflecting the company's financial performance in terms of profitability and operating efficiency. The analysis revealed that the company had a reasonable Total Asset Turnover compared to the industrial average. However, the company's financial performance in terms of profitability was very poor and well below the industry average which indicated that the company had a problem in generating profit from its sales.

Table 5.9: The bottled water company's financial performance at the end of 2010 (period 1)

ROA	-0.034
Net Profit Margin (%)	-4.89%
Total Asset Turnover (times)	0.7

Based on Du Pont analysis results, the priorities of the financial performance factors can be determined following the procedures illustrated in section 4.4.

Structured interviews were conducted with a group of decision makers consisting of four experts at the strategic level in order to assign the priorities of the financial performance factors - with respect to Du Pont analysis results- using the pair-wise questionnaire's scale (see figure 4.4). The interviews' protocol is illustrated in Appendix 3.4.

As presented in table 5.10, the first, second and fourth experts (managing director, business planning manager and financial manager) suggested that to enhance the financial performance, it is strongly more important for the company to focus on increasing profitability (*P*) than improving operating efficiency (*E*); while the third one (supply chain manager) believed that increasing profitability is demonstrably more important. G.MEAN was calculated to aggregate the experts' responses.

Table 5.10: The experts' consolidated responses on the questionnaire for assigning the priorities of the bottled water company's financial performance factors

	EXP.1	EXP.2	EXP.3	EXP.4	G.MEAN
P VS. E	5	5	7	5	5.4388

Based on the G.MEAN value, the pair-wise comparison matrix was established in order to express the consolidated opinions of the experts. For this pair-wise comparison matrix, the

Eigenvector method was used for weight calculation and the priorities of the financial performance factors were determined as follows:

Profitability (*P*) 84.5% and Efficiency (*E*) 15.5%.

$$\begin{array}{c} \\ P \\ E \end{array}\begin{array}{c} \begin{array}{cc} P & E \end{array} \\ \begin{vmatrix} 1 & 5.4388 \\ 0.18 & 1 \end{vmatrix} \end{array}$$

where 5.4388 is the G.MEAN value while 0.18 is the reciprocal value of the G.MEAN

According to these results, the higher priority to enhance financial performance was given to the profitability factor with a priority weight of 84.5% compared to only 15.5% assigned to the efficiency factor.

The results revealed that for the new accounting period 2011 (period 2), enhancing the financial performance can be achieved through focusing on SC performance measures that drive profitability components.

5.5.3 <u>Determining the relative weights of the five main SC performance measures with respect to the financial performance priorities</u>

Following the procedures illustrated in section 4.4, the group of decision makers was asked to rank the five main SC performance measures priority with regard to each financial performance criterion. Structured interviews were conducted using a 4 unit scale questionnaire (3, 5, 7 and 9) as a basis for discriminating levels of preference, where:

- 3 stands for slightly more important,
- 5 for strongly more important,
- 7 for demonstrably more important and
- 9 for absolutely more important.

Figures 5.18 and 5.19 present questionnaire forms to facilitate comparison of the importance of the SC main performance measures with respect to profitability and efficiency factors respectively. The interview protocol and the survey procedures are included in Appendix 3.5.

With respect to (Profitability)	Importance or preference of one factor over the frame of discernment θ (all D.A.'s)	
Attribute	Absolutely more important (9) Demonstrably more important (7) strongly more important (5) Slightly more Important (3) Slightly more Important (3) strongly more important (5) Demonstrably more important (7) Absolutely more important (9)	Attribute
RL		θ
RS		θ
CO		θ
AG		θ

Figure 5.18: Questionnaire form to facilitate comparison of the importance of SC main performance measures with respect to profitability factor

With respect to (Efficiency)	Importance or preference of one factor over the frame of discernment θ (all D.A.'s)	
Attribute	Absolutely more important (9) Demonstrably more important (7) strongly more important (5) Slightly more Important (3) Slightly more Important (3) strongly more important (5) Demonstrably more important (7) Absolutely more important (9)	Attribute
RL		θ
RS		θ
AM		θ

Figure 5.19: Questionnaire form to facilitate comparison of the importance of SC main performance measures with respect to efficiency factor

The initial knowledge matrices, which represented the consolidated opinions of the decision makers for ranking the five main SC performance measures priority with regard to each financial performance criterion, were established based on the survey responses (table 5.11).

Table 5.11: Initial knowledge matrices for the bottled water company's financial performance criteria

Initial knowledge matrix for profitability (P)						**Initial knowledge matrix for efficiency (E)**				
P	RL	RS	AG	CO	θ	**E**	RL	RS	AM	θ
RL	1	0	0	0	1.73	RL	1	0	0	1.73
RS	0	1	0	0	1.73	RS	0	1	0	1.73
AG	0	0	1	0	4.79	AM	0	0	1	6.85
CO	0	0	0	1	5.92	θ	0.58	0.6	0.15	1
θ	0.58	0.6	0.21	0.17	1					

Then, as shown in table 5.12, according to DS/AHP method the priority values of financial performance factors were incorporated into each of the initial decision knowledge matrices.

Table 5.12: Knowledge matrices for the bottled water company's financial performance criteria after influence of their priority rating

Knowledge matrix for profitability (P) after influence of its priority rating						**Knowledge matrix for efficiency (E) after influence of its priority rating**				
P	RL	RS	AG	CO	θ	**E**	RL	RS	AM	θ
RL	1	0	0	0	1.5	RL	1	0	0	0.27
RS	0	1	0	0	1.5	RS	0	1	0	0.27
AG	0	0	1	0	4	AM	0	0	1	1.06
CO	0	0	0	1	5	θ	3.72	3.72	0.9	1
θ	0.68	0.68	0.2	0.2	1					

Using the knowledge matrices for each of the criteria, the normalised knowledge vectors were produced following the traditional AHP method as illustrated in table 5.13.

Table 5.13: The normalised knowledge vectors of the bottled water company's main SC performance measures for each of the financial performance factors

Profitability(P)		**Efficiency (E)**	
RL	10.5%	RL	8.1%
RS	10.5%	RS	8.1%
AG	28.9%	AM	31.9%
CO	35.8%	θ	51.9%
θ	14.3%		

These normalised pieces of evidence were combined by applying Dempster's rule of combination on sources of information *P* and *E* and the following data was generated:

m1(P) \ m2(E)	$m2(E)_{RL}$= 0.104753	$m2(E)_{RS=}$ 0.104753	$m2(E)_{AG}$= 0.289498	$m2(E)_{CO}$= 0.3578	$m2(E)_{AM}$ = 0	$m2(E)_{\theta}$= 0.143198
$m2(E)_{RL}$=0.080675	0.008451 {RL}	0.008451 {Φ}	0.023355 {Φ}	0.028866 { Φ}	0 { Φ}	0.011553 {RL}
$m2(E)_{RS}$=0.080675	0.008451 { Φ}	0.008451 {RS}	0.023355 { Φ}	0.028866 { Φ}	0 { Φ}	0.011553 {RS}
$m2(E)_{AG}$ =0	0 { Φ}	0 { Φ}	0 {AG}	0 {Φ}	0 { Φ}	0 {AG}
$m2(E)_{CO}$ =0	0 { Φ}	0 { Φ}	0 { Φ}	0 {CO}	0 { Φ}	0 {CO}
$m2(E)_{AM}$=0.319185	0.033435 { Φ}	0.033435 { Φ}	0.092404 { Φ}	0.114205 { Φ}	0 {AM}	0.045707 {AM}
$m2(E)_{\theta}$=0.519464	0.054414 {RL}	0.054414 {RS}	0.150384 {AG}	0.185864 {CO}	0 {AM}	0.074386 {θ}

Degree of conflict (K) =0.394822

Normalised factor (1-K) =0.605178

$m_{1\text{-}2}(A)_{RL} = 0.074417/0.605178=0.122968$

$m_{1\text{-}2}(A)_{RS} = 0.074417/0.605178=0.122968$

$m_{1\text{-}2}(A)_{AG} = 0.150384/0.605178=0.248496$

$m_{1\text{-}2}(A)_{CO} = 0.185864/0.605178=0.307123$

$m_{1\text{-}2}(A)_{AM} = 0.045707/0.605178=0.075526$

$m_{1\text{-}2}(A)_{\theta} = 0.074386/0.605178=0.122917$

Then, the overall BPA for SC performance measures ($m_{sc\ performance\ measures}$) was constructed, and consequently the relative importance weights of the five main SC performance measures were ranked. As illustrated in table 5.14, CO and AG are the most important SC performance criteria to focus on for the purpose of linking SC processes' performance to the company's short-term strategic financial priorities. Also from table 5.14, it can be noticed that the sum of the relative importance weights of the five main SC performance measures equals only 0.88, indicating an ignorance factor equal to 0.12.

Table 5.14: The relative importance weights of the bottled water company's main SC performance measures with respect to the financial performance priorities

Subsets	SUMm1(P)M2(E)	$m_{sc\ performance\ measures}$	Weight(W)	Priority
RL	0.074417	0.122968	12%	3
RS	0.074417	0.122968	12%	3
AG	0.150384	0.248496	25%	2
CO	0.185864	0.307123	31%	1
AM	0.045707	0.075526	8%	4
θ	0.074386	0.122917		

Since the company's SC operations performance and the overall financial performance have been measured and the focus areas for enhancing the company's performance have been identified; the data analysis phase can be conducted in order to draw conclusions and prepare the case study report.

5.6 Phase five: Data analysis phase

In the analysis phase, current SC operations' performance for the year ended December 31st 2010 is evaluated and analysed through assessing the efficiency and the effectiveness of current SC operational strategy. Consequently, SC operational strategy for the new accounting period (2011) is formulated based on the company's short-term strategic financial priorities. Finally, feedback on implementing the SCM KPIs system in the bottled water company for one year (2010) is collected and analysed. The detailed steps of the data analysis phase are presented below.

5.6.1 Evaluating the efficiency and the effectiveness of current SC operational strategy

The performance rate (R) of the five main SC performance measures at the top level of the SCOR hierarchy were adjusted by their relative importance weights (W) with respect to the priorities of the company's financial performance. The weighted rates of all performance measures were then aggregated in order to calculate the company's SCFLI.

As illustrated in table 5.15, SCI assigned equal weight (20%) in the aggregation procedure to the five main SC performance measures at the top level of the SCOR hierarchy. On the other hand, SCFLI took into consideration the relative importance weights of the five main SC performance measures. It multiplied the performance rate of the five main SC performance measures by their relative importance weights in order to reflect the extent to which SC operations' performance was linked to the company's short-term strategic financial objectives.

SCI evaluated SC operations' performance; however it didn't reflect the impact of such performance on the company's overall financial performance. SCFLI index revealed the effectiveness and the efficiency of supply chain operations in meeting short-term strategic financial objectives. Through analysing this index, the company can identify the significant contribution of each performance measure to the overall company's financial performance and identify low performance measures in order to formulate new SC operational strategy for better alignment with the company's strategic financial priorities.

Table 5.15: Calculating SCFLI of the bottled water company for the year ended December 31st 2010

Measure	**SCI**			**SCFLI**			**Assessment rate**
	R	W	WR	R	W	WR	
RL	0.72	20%	0.143	0.72	12%	0.086	VG
RS	0.62	20%	0.123	0.62	12%	0.074	VG
AG	0.64	20%	0.127	0.64	25%	0.159	VG
CO	0.29	20%	0.059	0.29	31%	0.091	P
AM	0.53	20%	0.105	0.53	8%	0.042	G
SUM	2.8	100%	0.557	2.8	88%	0.452	G

By adjusting the relative importance weights of the five main SC performance measures, the company's SCFLI was calculated to be 0.514 revealing the good contribution on average of SC operations' performance in enhancing the overall financial performance (see equation 2).

$$\textit{Supply chain financial link index (SCFLI)} = \frac{\sum WR}{\sum W} = \frac{0.452}{0.88} = 0.514 \qquad (2)$$

The analysis of this index indicated that for better alignment with the company's short-term strategic financial objectives in the new accounting period (2011), SC operational strategy should focus on managing the performance of SC processes to which cost measures correspond. Since SC cost measures had poor performance and a relatively high importance with respect to the company's short term strategic financial priorities, managing SC costs can have a significant impact on the overall financial performance.

5.6.2 Formulating new SC operational strategy based on the company's short-term strategic financial priorities

Based on the previous analysis, the company's short-term strategic financial objective would be improving its profitability particularly through managing its costs and this consequently would lead to assigning the highest priority weight at the top level of the SCOR hierarchy to cost measures. Therefore the appropriate supply chain operational strategy to align with the company's strategic financial priorities would focus on enhancing the processes to which cost performance measures correspond.

Figure 5.20 illustrates the contribution of each cost performance measure - at different levels of the SCOR hierarchy up to level 2 metrics - to the overall aggregated SC cost performance at level 1 metrics in 2010. As shown in figure 6.11, freight expense, direct marketing expense, direct sales expense, labour (L) costs and indirect costs related to making product were high resulting in very poor performance (***VP***) with respect to the performance rating scale. Material cost (M) had poor performance (***P***); while excellent performance (***E***) was assigned to administrative expense.

Node ▲

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
CO									
Node : CO									
CO 1.1	Supply Chain Management Cost	تكاليف إدارة سلسلة الإمداد	.2	1	.33		P	.256	.084
CO 1.2	Cost of Goods Sold	تكلفة البضاعة المباعة	.2	1	.67		P	.312	.209
CO 2.1	Freight expense	مصاريف النقل	.17	.11	.65	.17	VP	.2	.13
CO 2.2	Direct marketing expense	مصاريف تسويقية مباشرة	.08	.04	.07	.08	VP	.2	.014
CO 2.3	Direct sales expense	مصاريف بيعية مباشرة	.2	.15	.21	.21	VP	.2	.042
CO 2.4	Administrative expense	مصاريف ادارية	.02	.01	.07	.01	E	1	.07
CO 2.5	Cost to Make	تكلفة مراحل التصنيع	.2	1			-		
CO 3.1	M Cost	تكلفة المواد	.75	.54	.56	.67	P	.4	.224
CO 3.2	L Cost	تكلفة الأجور	.15	.09	.15	.14	VP	.2	.03
CO 3.3	Indirect Costs Related To Making Product	التكاليف الصناعية الغير مباشرة	.25	.14	.29	19	VP	.2	.058

Figure 5.20: The aggregated performance of the bottled water company's SC cost measures

To improve the performance of SC costs, the formulated SC operational strategy should focus on managing SC costs that had low performance and a relatively high importance weight. The company can then determine the objectives and action plans required to implement this strategy.

Due to the long distance and poor road network between the plant and the market, the freight expense has a high importance weight and consequently, a significant impact on the overall performance of SC costs.

The company has limited control on activities such as sales, marketing and distribution due to the fact that these activities are under the control of the parent company or other sister companies. Direct sales expense has a relatively high importance weight which contributes to the inability to manage SC costs. Although direct marketing expense was high, its low importance weight has resulted in a low impact on the overall SC costs performance.

Labour cost had a very poor performance, however it had a relatively low importance weight comparing to other components of cost to make (M cost and indirect cost related to making products). Focusing on enhancing these other components especially M cost can result in a greater impact on enhancing the overall SC costs performance.

Based on the analysis of SC costs, SC cost performance measures that require improvement have been identified. The highest priority should be assigned to SC processes to which the freight expense measure corresponds. Since the freight expense measure had a very poor performance and the highest relative importance weight, managing freight expense could highly impact SC cost performance. The second priority should be managing SC processes that impact M cost. M cost had a poor performance and the highest relative importance weight compared to other cost to make measures. The third priority should be given to direct sales expense as it had a very poor performance and a relatively high importance weight. The fourth priority should be managing indirect costs related to making product. While a lesser priority should be assigned to L cost and direct marketing expense.

Table 5.16 illustrates the objectives and the plan of actions at level one of the SCOR model to implement the formulated SC operational strategy. As shown in table 5.16, level 1 objective should be to reduce SC costs to reach the level at which maximum performance could be achieved. For example freight expense represented 17% of total SC management cost resulting in a very poor (VP) performance. Reducing freight expense by 6.2 percentage points- to be 10.8% of total SC management cost- will lead to achieving the maximum targeted performance in terms of managing SC's freight expense. However, it should be noted that these objectives are not mutually exclusive. The interrelationship between SC costs may result in the increasing in the contribution in one cost when another cost is lowered. Cost trade-offs should be considered by giving priorities for costs that have a relatively high importance weight in order to achieve a higher impact on the overall SC costs performance. In addition, the decision to lower costs should be taken at a level that will not affect the effectiveness of SC processes to which SC cost measures correspond, or the effectiveness of any other processes in the SC that have interrelationships with such processes.

Table 5.16 also identifies the departments responsible for carrying out the plan of action. Since the SC processes' map assigned a department responsible for each process, the departments responsible for SC processes to which SC cost measures correspond can be identified. Finally, key performance indicators to evaluate the effectiveness of accomplishing the planned objectives are identified based on SCOR model level 1 metrics. SC costs' key performance indicators are classified into two main categories: supply chain management cost and cost of goods sold.

Table 5.16: The bottled water company's SC operational strategy

Strategic aim	**Level 1 objectives**	**Level 1 plan of action**	**Corresponding processes**	**Responsibilities**	**Key performance indicators at level 1 metrics**
Managing Supply Chain Costs	Reducing freight expense by 6.2 percentage points	Redesigning distribution network Searching for freight service providers at lower rates with the same quality	D1 (Deliver Stocked Product)	Commercial department	Supply Chain Management Cost
	Reducing direct material cost (M) by 13 percentage points	Searching for other suppliers at lower price with the same quality	M1 (Make-to-Stock)	Commercial department	Cost of Goods Sold
	Reducing direct sales expense by 5.7 percentage points	Remapping the distribution channels	D1	The distribution company	Supply Chain Management Cost
	Reducing indirect costs related to making product by 5.5 percentage points	Proposing a plan to optimise the efficiency of indirect costs related to making product	M1	Follow-up department, Production department and Engineering department	Cost of Goods Sold

	Reducing labour cost (L) by 5 percentage points	Minimising 3 shifts days to 2 shifts days while maintaining the same target outputs	M1	Production department and Engineering department	Cost of Goods Sold
	Reducing direct marketing expense by 4.4 percentage points	Shifting from the traditional marketing mediums to social media marketing	D1	The distribution company	Supply Chain Management Cost

Since the bottled water company's SC operational strategy for the new accounting period (2011) has been formulated, the next step is to apply such strategy and then evaluate its efficiency and effectiveness to improve the financial performance.

To measure and evaluate the contribution of the newly proposed SC operational strategy in achieving the company's short-term strategic financial objectives, SCFLI needs to be calculated again at the end of the new accounting period (2011) after applying the newly formulated SC operational strategy. Finally, the Du Pont ratio should be recalculated and analysed to test the impact of improving SC operations' performance on enhancing the company's overall financial performance.

However, the accessibility of the case study company was limited to testing the current situation and making suggestions for the improvement. It was not possible for the researcher to apply the newly proposed SC operational strategy in the company and test its impact. For the bottled water company, SC operations' performance was assessed and analysed through calculating the SCI.

Also the SCFLI was calculated to measure and evaluate the extent to which SC operations' performance was aligned with the financial strategy. Based on these results, the focus area for enhancing the financial performance was determined also SC processes which need improvement were identified and a suitable corresponding SC operational strategy was suggested. Due to the limited access, the suggested strategy was not applied and as a result the researcher was not able to test its impact on improving SC operations' performance or on enhancing the overall financial performance.

To overcome the limitation of not being able to apply the suggested strategy and collect data for one more period, the current real situation of the bottled water company is extended numerically. In the next part, the researcher assumes that the suggested strategy would be applied to demonstrate how improving the relevant SC operations could influence the outcome in terms of the company's financial performance after a financial year.

Assuming the proposed SC operational strategy was implemented, SC total cost would decrease by 28.8% between 2010 to 2011. Consequently, the changes in SC costs would impact the performance of the related SC performance measures. As illustrated in Table 5.17, SC cost measures and some of the SC asset management measures would be affected positively by decreasing SC costs resulting in improvement in the overall SC performance assuming that all other variables would not change and remain constant. As a result, SCI for the year ended 2011 would increase to be 0.717 (see figure 5.21) revealing very good SC operations' performance for this period.

Table 5.17: The performance of the related SC performance measures before and after applying the suggested SC operational strategy

Supply Chain Cost measures	**Equation**	**For the year ended 2010**	**For the year ended 2011**
Freight expense (% of total cost)	Freight expense / total cost	17%	10.8%
Direct marketing expense (% of total cost)	Direct marketing expense / total cost	8%	3.6%
Direct sales expense (% of total cost)	Direct sales expense / total cost	21%	15.3%
Administrative expense (% of total cost)	Administrative expense / total cost	1%	0.9%
Material Cost (% of total manufacturing cost)	M Cost / total manufacturing cost	67%	54%

Labour Cost (% of total manufacturing cost)	L Cost / total manufacturing cost	14%	9%
Indirect Costs Related To Making Product (% of total manufacturing cost)	Indirect Costs Related To Making Product / total manufacturing cost	19%	13.5%
<u>Supply Chain Asset Management measures</u>			
Return on Working Capital	Net profit /(Inventory +Accounts Receivable - Accounts Payable)	-1%	5%
Return on Supply Chain Fixed Assets	Net profit / total fixed assets	-6%	31%
Return on Supply Chain total Assets	Net profit /total assets	-3.42%	17.7%

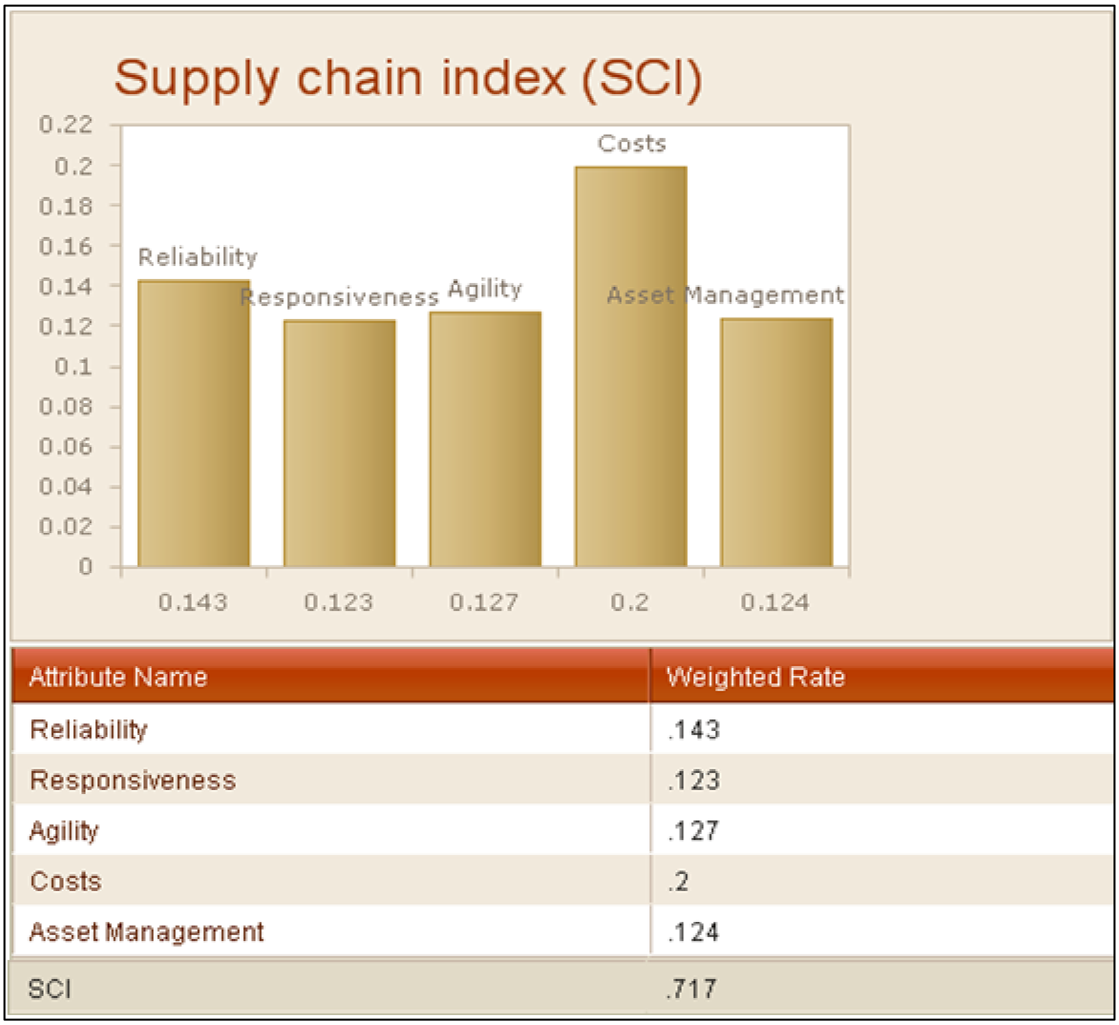


Figure 5.21: The bottled water company's SCI (2011)

Table 5.18 summarises the bottled water company's SC performance and overall financial performance before and after applying the newly proposed SC operational strategy. SCI (2010) was 0.56 reflecting good performance on average of the company's SC operations. SCI (2011) would increase to be 0.717 revealing improvement in the company's SC performance after applying the suggested SC operational strategy. By analysing this index, it is obvious that the performance of SC processes to which cost and asset management measures correspond would improve after applying the suggested SC operational strategy, while the performance of SC processes to which reliability, responsiveness and agility measures correspond are assumed to remain constant.

The table also shows improvements in the financial performance after applying the suggested SC operational strategy. Managing SC costs would impact financial performance components (revenue, cost and assets). The company's total costs would be affected directly, while revenue and assets would be affected indirectly through increasing Net Income and efficiency of asset management. Du Pont results at the end of 2011 would show improvement in Net Profit Margin and ROA which reflects the impact of managing SC costs on achieving the targeted financial outcome (improving profitability) and consequently, contributing to enhancing the company's overall financial performance. The bottled water company's SCFLI (2011) would increase by approximately 26 percentage points and by 50% compared to 2010 revealing improvement in the efficiency and the effectiveness of SC operational strategy in connecting to the company's short-term strategic financial objectives.

Table 5.18: The bottled water company SC operations' performance and overall financial performance before and after applying the suggested SC operational strategy

Measure	Period 1	Period 2	Change direction
SC operations' performance			
RL	0.143	0.143	No change
RS	0.123	0.123	No change
AG	0.127	0.127	No change
CO	0.059	0.2	Favourable
AM	0.105	.124	Favourable
SCI	**0.56**	**0.717**	**Favourable**

Financial performance			
Net Profit Margin (%)	-4.89%	25%	Favourable
Total Asset Turnover (times)	0.7	0.7	No change
ROA	-0.0342	0.18	Favourable
SCFLI	**0.514**	**0.772**	**Favourable**

In this section, the current actual situation of the bottled water company has been evaluated and analysed. The analysis revealed that the company had poor profitability particularly due to the poor performance of SC processes to which cost measures correspond. To improve the company's profitability, an appropriate supply chain operational strategy was formulated allocating the highest priority throughout the SCOR hierarchy to cost measures.

First, the company's financial performance was evaluated and analysed using Du Pont ratio analysis. Based on this analysis, the priorities of financial performance factors were determined using the classical AHP technique and the company's short-term strategic financial objectives were identified.

To link SC operations' performance to the company's short-term strategic financial objectives, DS/AHP approach was conducted to determine the relative importance weights of the five main SC performance measures with respect to the priorities of financial performance factors. Based on the relative weights of SC performance measures and the priorities of financial performance factors, the company's new SC operational strategy for the new accounting period was formulated.

SCFLI was calculated before and after applying the new SC operational strategy by aggregating the weighted rates of the five main SC performance measures at the top level to reveal the significant contribution of the newly formulated SC operational strategy in achieving the company's short-term strategic financial objectives. Finally, the Du Pont ratio was calculated again by the end of the new period to test the impact of improving SC operations' performance on enhancing the overall financial performance of the company. Feedback on implementing SCM KPIs system in the bottled water company is presented in the next section.

5.6.3 Feedback on implementing SCM KPIs system in the bottled water company

Feedback on the SCM KPIs system was collected and analysed after implementing it in the bottled water company for one year (2010). The feedback aimed at identifying costs and benefits, the perceived advantages and limitations of implementing this system and suggestions for improving it (see Appendix 12).

The feedback revealed that no changes were required to apply this system; only one data entry clerk was hired. The system allowed the company to establish a database including all information related to supply chain functions as well as applying a coding system for all items related to the supply chain processes which helped in monitoring the efficiency of each process and setting the necessary strategies. The implementation of this system was an opportunity for the staff to get more awareness about all supply chain stages, terms and advantages as well as providing a clear vision for all department heads in relation to the supply chain stages and functions and how each function affects the other. In addition, it provided a vision for the separation between department functions in order to coincide with supply chain stages to give a better result especially as the bottled water company will implement SAP system soon which will ultimately necessitate this separation.

Having this system allowed the top management to identify supply chain processes that need improvement and to focus on the problematic areas especially:

- Monitoring direct and indirect materials sourcing with respect to the performance of each supplier in relation to planned vs. delivered quantities and accuracy in the delivery as main issues in measuring Egyptian suppliers' performance.
- Monitoring the percentage of spoilage materials regularly in order to handle any problem in relation to the quality of the supplied materials.
- Monitoring scheduled and unscheduled equipment downtime in order to measure machine efficiency in relation to its origin and its effect on the ROI, in addition to monitoring the performance of the maintenance team.
- Monitoring the factory production process in relation to the outcome of each production hour and analysing and solving any problem which affects the outcome per hour.

5.7 Conclusion

The five phases for conducting the case study have been presented in this chapter. The first two phases provided an insight into the Egyptian bottled water sector generally and the bottled water company particularly. In the first phase (case design and preparation for data collection), the Egyptian bottled water sector was described and analysed. In addition, case study nominations from this sector were screened and the appropriate case study was selected. The introductory phase provided a holistic view of the case study company. During this phase, the characteristics, the structure and the strategy of the bottled water company's existing supply chain were described and analysed.

In the third phase, the SCOR FAHP technique was established in the bottled water company. Based on the SCOR model, the main processes and sub processes were mapped and their corresponding performance measurement attributes were identified. Then, the relative weights of the company’s performance measurement attributes were determined following the methodology illustrated in chapter four. Finally, a performance rating scale for SC performance measurement attributes was established in order to determine the company’s supply chain performance index (SCI) through calculating and aggregating the weighted rates of all performance measurement attributes.

In the implementation phase, the company’s current SC operations performance and financial performance were measured. SCM KPIs system was designed and implemented to evaluate SC operations’ performance and calculate the SCI. Then, the priorities of financial performance factors were identified, upon which the relative importance weights of the five main SC performance measures were calculated.

The analysis phase assessed the efficiency and the effectiveness of current SC operational strategy, then the newly proposed SC operational strategy was formulated based on the company's short-term strategic financial priorities. Finally, feedback was collected and analysed on the implementation of the developed research method in the bottled water company. Chapter six will provide summary and interpretation of findings presented in this chapter along with discussion of the implications of these findings.

CHAPTER SIX - DISCUSSION

6.1 Introduction

In the previous chapter, five major phases were carried out to conduct the case study. This chapter discusses in detail the significance of key findings from the case study in relation to the research proposition posed for this study and to previous research. Scenario analyses are proposed to illustrate how the research method can be applied in various possible financial performance results.

The chapter starts by evaluating the realisation of the research proposition. Then section 6.3 presents the scenario analysis approach through illustrating five main alternative scenarios. The significance of key findings in relation to previous research is discussed in section 6.4. The chapter concludes in section 6.5 by presenting the applied framework based on the research findings.

6.2 Validation of the research proposition

The research proposition assumed that "Utilising the relationship between a company's SC operations performance and its financial performance can allow the company to develop a procedure to identify and implement SCM practices by which financial performance can improve." The study proposition as derived from previous studies in the area of SCM demonstrated the relationship between SCM practices and financial performance improvements. This theoretical proposition was tested and confirmed empirically by creating and implementing a framework linking SC operations' performance to the company's strategic financial objectives.

As illustrated in the previous chapter, results from the case study showed improvements in the financial performance after applying the suggested SC operational strategy. The case study findings confirmed the theory obtained from previous studies concerning the positive effects of SCM on an organisation's performance (see section 2.5).

Conducting a case study of an Egyptian bottled water company verified the applicability of the research framework in the manufacturing sector. The results showed that the bottled water company's financial performance in terms of profitability for the year ended December 31st 2010 was very poor. The company's SC operations performance for the same year was evaluated and analysed following the research procedure. The SCI in 2010 was 0.56 revealing that the company's SC performance in this period was good on average. By analysing this index, it was found that the performance of SC processes to which costs measures correspond was poor, while the performance of SC processes to which asset management measures correspond was good; and the performance of SC processes to which reliability, responsiveness and agility measures correspond was very good.

Based on the bottled water company's performance results in 2010, the targeted financial outcome in the new accounting period (2011) was identified. In 2011, the company aimed at improving profitability, particularly through managing SC costs. The highest importance weight at the top level of the SCOR hierarchy was assigned to cost measures and as a result, SC operational strategy focused on enhancing the processes to which cost performance measures correspond. Cost performance measures that require improvement and their relevant SC processes were identified. The highest priority was assigned to SC processes to which the freight expense measure corresponds. The second priority was given to SC processes that impact material cost; while the third priority was assigned to direct sales expense.

Due to the limited access, the suggested strategy was not applied and the current real situation of the bottled water company was extended numerically. The researcher assumed that the suggested strategy would be applied to demonstrate how improving the relevant SC operations could influence the outcome in terms of the company's financial performance after a financial year. The results showed improvements in the financial performance after applying the suggested SC operational strategy which confirmed the critical relationship, derived from previous theories and research, between SC operations' performance and the company's financial performance.

However, it was an optimistic assumption to suppose that the company would carry out the proposed strategy in full and as a result, all objectives would be accomplished. The previous assumption theoretically assumed that the company can optimally achieve the maximum targeted performance for all SC cost measures with respect to the performance rating scale.

It should be noted that practically companies usually have trade-offs between performance objectives which prevent them from achieving the optimum performance of all objectives at the same time. In real life, companies may focus on achieving the objectives that have the highest priorities or they may combine the objectives with different percentages.

Table 6.1 shows how the results would change if the proposed strategy was partially undertaken. Another two conditions are assumed (normal condition and pessimistic condition). The normal condition assumes that only the first four objectives would be accomplished (reducing freight expense, reducing direct material cost, reducing direct sales expense and reducing labour cost). The pessimistic condition assumes that only the first two objectives would be accomplished (reducing freight expense and reducing direct material cost).

Under the normal condition, SC total cost would decrease by 21.8% from 2010 to 2011, while it would decrease by 13.2% under the pessimistic condition. The results under both condition show improvement in SC performance as well as financial performance. SCI would improve to be 0.68 in the normal condition and 0.64 in the pessimistic condition revealing improvement in the company's SC operations performance under both conditions. Also the SCFLI would increase to reach 0.71 under the normal conditions and 0.656 under the pessimistic conditions which reflects the improvement in the efficiency and the effectiveness of SC operational strategy in connecting to the company's short-term strategic financial objectives. Many other conditions could happen; however, as shown in the previous three assumed conditions, any improvement in the SC operations' performance will lead to better SCM, and consequently enhance the company's overall financial performance.

Table 6.1: The bottled water company's performance before and after applying the suggested SC operational strategy having three possible conditions (optimistic, normal and pessimistic)

Supply Chain Cost measures	**For the year ended 2010**	**For the year ended 2011**		
		Optimistic condition	**Normal condition**	**Pessimistic condition**
Freight expense (% of total cost)	17%	10.8%	10.8%	10.8%
Direct marketing expense (% of total cost)	8%	3.6%	8%	8%
Direct sales expense (% of total cost)	21%	15.3%	15.3%	21%
Administrative expense (% of total cost)	1%	1%	1%	1%
Material Cost (% of total manufacturing cost)	67%	54%	54%	54%
Labour Cost(% of total manufacturing cost)	14%	9%	9%	14%
Indirect Costs Related To Making Product (% of total manufacturing cost)	19%	13.5%	19%	19%
Percentage decrease in SC total cost from 2010 to 2011		28.8%	21.8%	13.2%
Supply Chain Asset Management measures	**For the year ended 2010**	**For the year ended 2011**		
		Optimistic condition	**Normal condition**	**Pessimistic condition**
Return on working capital	-1%	5%	3.7%	1.8%
Return on Supply Chain Fixed Assets	-6%	31%	22%	11%
Return on Supply Chain total Assets	-3.42%	18%	12.6%	6.3%
Supply chain's performance indices	**For the year ended 2010**	**For the year ended 2011**		
		Optimistic condition	**Normal condition**	**Pessimistic condition**
SCI	0.56	0.717	0.68	0.64
SCFLI	0.567	0.772	0.71	0.656

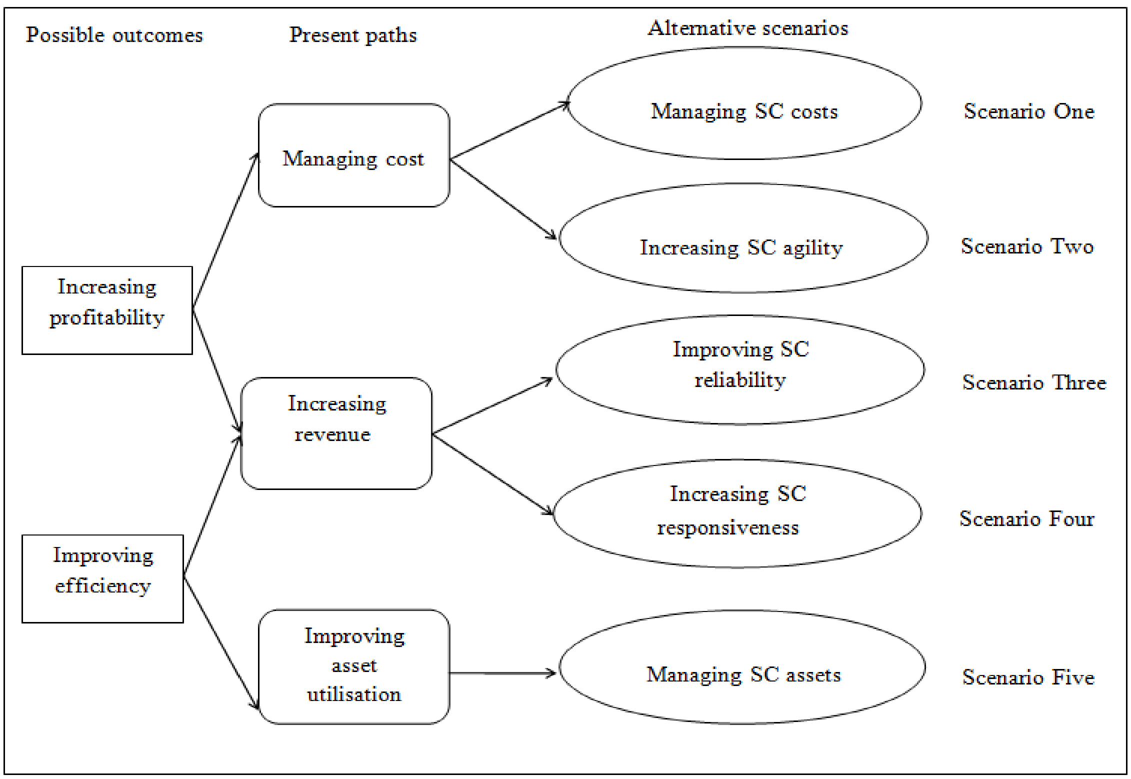
In the next section, a scenario analysis approach is developed to illustrate how SC operational strategy can be linked to a company's financial performance according to various possible financial performance results and to identify the most appropriate SC operational strategy with regard to the targeted financial outcome.

6.3 Scenario analysis

Porter (1985) defined scenarios as "*an internally consistent view of what the future might turn out to be — not a forecast, but one possible future outcome*". Another definition for scenarios was introduced by Ratcliffe (2000, p.4) as "*an approach that involves developing future environment situations and describing the path from any given present situation to these future situations*". Scenario analysis is not forecasting of the future but the exploration of alternative situations that could possibly happen in the future and proposing strategies to respond to these future alternatives given different possible present paths leading to such alternatives (Mietzner and Reger, 2005; Dutta and Babbel, 2010). It can be used as a strategic decision making tool focusing on identifying the most appropriate actions under different possible future circumstances (Duinker and Greig, 2007).

In this section, five main alternative scenarios are established based on the method proposed by Presutti Jr. and Mawhinney (2007) to link SC performance metrics to the company's financial performance. This method was developed further in this research by incorporating Du Pont analysis in the financial performance metrics to illustrate the impact of SC performance on financial performance through assessing the contribution of each financial performance driver (revenue, cost and assets) to the improvement of the company's profitability and operating efficiency (see figure 3.4).

As presented in figure 6.1, the analysis of a company's financial performance may result in one of two main targeted outcomes: increasing profitability or improving efficiency. Based on the result of the Du Pont ratio analysis, the priorities of financial performance objectives (profitability or efficiency) are determined. If the analysis reveals that the company has a problem in generating profit from its sales, then the focus area for enhancing the financial performance should be to increase profitability. On the other hand, if the analysis reveals that the company has a problem in generating sales from assets employed in business, then the focus area for enhancing financial performance should be to improve efficiency.



(Source: The author, Elgazzar et al., 2012b)

Figure 6.1: The main possible targeted financial outcomes and their corresponding scenarios

These targeted financial outcomes can be achieved through three different paths: increasing revenue, managing costs and improving asset utilisation. The appropriate path can be identified through assessing the contribution of each financial performance driver (revenue, cost and assets) to the company's financial performance in terms of profitability and operating efficiency.

Figure 6.1 demonstrates five main alternative scenarios that can be established with respect to these three different paths. However, these five scenarios are not mutually exclusive. They can be combined with each other resulting in more possible scenarios. For each path, the source of poor performance in terms of specific SC processes is traced and the corresponding SC performance measurement category (reliability, responsiveness, cost, agility and asset management) is identified. Consequently, the relevant scenario is determined and the appropriate SC operational strategy can be formulated. Scenario One (managing SC costs) - as the current real situation of the bottled water company- has been discussed and extended numerically in section 6.3.2 (Elgazzar et al., 2012b). The other four alternative scenarios (Scenario Two, Scenario Three, Scenario Four and Scenario Five) are discussed below.

6.3.1 Scenario Two (increasing SC agility)

Both Scenarios One and Two are relevant when the company's short-term strategic financial objective (i.e. the targeted financial outcome) is to increase its profitability and the analysis of financial performance results highlights cost as the financial driver that most requires attention. However, in Scenario Two, the SCI indicates that the performance of SC processes to which agility measures correspond register the poorest performance among all SC processes. As a result, the short-term strategic financial objective will be to increase profitability, particularly through increasing SC agility. As a result, the appropriate supply chain operational strategy to align with the company's strategic financial priorities will focus on enhancing the processes to which agility performance measures correspond. This consequently will lead to assigning the highest priority weight at the top level of the SCOR hierarchy to agility measures.

Table 6.2 suggests the objectives at the top level in the SC to accomplish the strategic aim of increasing SC agility. These objectives should be quantitatively measurable and can be translated into action plans needed to enhance the processes to which agility performance measures correspond. The key performance indicators to evaluate the effectiveness of accomplishing these objectives are identified based on SCOR model level 1 metrics.

Table 6.2: The appropriate SC operational strategy and corresponding level 1 objectives with regard to Scenario Two

Strategic aim	**Level 1 objectives**	**Responsibilities**	**Key performance indicators at level 1 metrics**
Increasing SC agility	Reducing the number of days required to achieve an unplanned sustainable 20% increase in quantities delivered by..... days.	Commercial department, Production department and Follow-up department	Upside Supply Chain Flexibility
	Increasing the maximum sustainable percentage of increase in quantity delivered that can be achieved in 30 days by.... percentage points.	Commercial department, Production department and Follow-up department	Upside Supply Chain Adaptability
	Increasing the maximum sustainable percentage of reduction in quantities ordered at 30 days prior to delivery with no inventory or cost penalties by.....percentage points.	Commercial department, Production department and Follow-up department	Downside Supply Chain Adaptability

The actual performance of the bottled water company's agility measures in 2010 at different levels of the SCOR hierarchy is illustrated earlier in figure 5.16. The aggregated SC agility performance at level 1 metrics resulted in very poor (***VP***) performance of upside SC flexibility, excellent (***E***) performance of upside SC adaptability and very good (***VG***) performance of down side SC adaptability.

As shown in figure 5.16, the upside flexibility of SC source, make and deliver processes was very poor resulting in very poor performance of the company's supply chain upside flexibility with respect to the performance rating scale. Upside adaptability measures of source and make processes had a relatively high importance weighting compared to upside deliver adaptability. Their excellent performance contributed to an excellent performance of SC upside adaptability. Although upside adaptability of deliver processes was poor, the relatively low importance weighting of upside deliver adaptability didn't have a great impact on the performance of SC upside adaptability. Downside source adaptability registered an excellent performance; however the poor performance of downside make adaptability and downside deliver adaptability negatively impacted the performance of SC down side adaptability.

Based on the pervious analysis, SC agility performance measures that require improvement can be identified. For better SC agility performance in the new accounting period, the bottled water company should focus on enhancing the performance of SC processes to which upside flexibility measures correspond. Since upside SC flexibility had a very poor performance, increasing upside SC flexibility could highly impact SC agility performance. The second priority should be directed towards managing SC processes that impact downside make and deliver adaptability, while the third priority should be assigned to upside deliver adaptability.

6.3.2 Scenario Three (improving SC reliability)

Both scenarios three and four are relevant when the analysis of financial performance results highlights revenue as the financial driver that most requires attention.

In Scenario Three, the SCI indicates that the performance of SC processes to which reliability measures correspond register the poorest performance among all SC processes in relation to the performance rating scale. Therefore, the relevant present path to improve financial results will be "increasing revenue" particularly through improving SC reliability. As a result, the appropriate supply chain operational strategy to align with the company's strategic financial priorities will focus on enhancing the processes to which reliability performance measures correspond. This consequently will lead to assigning the highest priority weight at the top level of the SCOR hierarchy to reliability measures.

Table 6.3 suggests the corresponding objectives at the top level in the SC and their key performance indicators based on SCOR model level 1 metrics that need to be improved to accomplish the strategic aim of improving SC reliability.

Table 6.3: The appropriate SC operational strategy and corresponding level 1 objectives with regard to Scenario Three

Strategic aim	Level 1 objectives	Responsibilities	Key performance indicators at level 1 metrics
Improving SC reliability	Increasing the percentage of orders meeting delivery performance, delivered to customer on-time including all items and quantities with complete and accurate documentation and no delivery damage to ....percentage points.	Commercial department, Production department, Quality department and Follow-up department	Perfect Order Fulfilment
	Minimising the maximum acceptable percentage of forecast error to ....percentage points	Planning department	Forecast Accuracy

Figure 6.2 presents the actual performance of the bottled water company's reliability measures in 2010 at different levels of the SCOR hierarchy. The aggregated SC reliability performance at level 1 metrics showed very good (***VG***) performance of SC processes to which reliability measures correspond. The company achieved a very good rate of perfect orders fulfilment. It registered an excellent delivery performance rate, at which all of the orders are received by customer in the quantities and the items committed. Also, a very good rate of orders delivered on the committed date and in perfect condition (without damage or defect) was achieved. While a good rate of orders delivered with complete and accurate documents was registered.

The aggregated performance of the bottled water company's forecast accuracy was very good (***VG***). Although forecast accuracy of SC source, make, deliver and source return was excellent, supply chain forecast accuracy and deliver return forecast accuracy were very poor.

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
RL									
Node : RL									
RL 1.1	Perfect Order Fulfillment	الدقة في إستيفاء الطلبيات	.2	1	.36		VG	.739	.266
RL 1.2	Forecast Accuracy	دقة التخطيط و التنبؤ	.2	1	.64		VG	.698	.447
RL 2.1	% of Orders Delivered in Full	نسبة الطلبيات التي تم إستيفائها كاملة(واردة أو صادرة بالكميات و النوعيات المحددة)	.2	1	.24		E	.844	.203
RL 2.2	Delivery Performance to Customer Commit Date	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد في الميعاد والمكان المتفق عليه	.2	1	.12		VG	.779	.093
RL 2.3	Perfect Condition	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد وفقا للجودة المتفق عليها	.2	1	.56		VG	.709	.397
RL 2.4	Documentation Accuracy	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد مرفق بها جميع المستندات المطلوبة صحيحة و كاملة	.2	1	.08		G	.577	.046
RL 2.5	Supply Chain Forecast Accuracy	دقة التخطيط و التنبؤ بسلسلة الإمداد ككل	.6	.8	.19	.564	VP	.2	.038
RL 2.6	Source Forecast Accuracy	دقة التخطيط و التنبؤ بأنشطة التوريد	.7	1	.17	1.555	E	1	.17
RL 2.7	Make Forecast Accuracy	دقة التخطيط و التنبؤ بمراحل التصنيع	.7	1	.27	.98	E	1	.27
RL 2.8	Deliver Forecast Accuracy	دقة التخطيط و التنبؤ بمراحل تسليم المنتج للعميل	.7	1	.16	.998	E	1	.16
RL 2.9	Source Return Forecast Accuracy	دقة التخطيط و التنبؤ بالمرتجعات للموردين	.7	1	.06	2.09	E	1	.06
RL 2.10	Deliver Return Forecast Accuracy	دقة التخطيط و التنبؤ للمرتجعات من العملاء	.6	.8	.15	.304	VP	.2	.03

Figure 6.2: The aggregated performance of the bottled water company's SC reliability measures

The forecast accuracy rate in 2010 for the integrated supply chain was 56%. SC forecast accuracy was determined based on the rate of achievement of the planned objectives. As illustrated in table 6.4, the bottled water company's SC objectives for 2010 have been developed, quantified and translated into the course of actions needed to achieve such objectives. The deviation of actual achievement from the planned objectives was calculated to determine SC forecast accuracy. Since supply chain forecast accuracy and deliver return forecast accuracy registered the worst performance rate among all reliability measures, the highest priority in the new accounting period should be assigned to enhancing the performance of SC processes to which these measures correspond.

Table 6.4: The bottled water company's SC forecast accuracy

Obj.	Description	How to measure	W	Forecast	Actual
1	Producing Carbonated Water	- Co_2 equipment Start Up 50% - Product launch 50%	0.1	100%	30%
2	Producing Cup size 200 ml	- Cup filling line Start Up 34% Negotiate mould with cup suppliers 33% - Product launch 33%	0.05	100%	0%
3	Producing bottle with cup size 0.5L	- Manufacture bottle 0.5 L mould with cup 50% - Finalising Label design 50%	0.15	100%	100%
4	Producing Pyramid bottle (Messallah)	- Product Launch 100%	0.05	100%	0%
5	Producing a new design of bottle size 0.6 & 1.5L	- Finalising new design 50% - Supply sleeve machine 50%	0.15	100%	100%
6	Producing Flavoured Water	- Production Line Start Up 34% - Choose bottle design 33% - Product launch 33%	0.1	100%	67%
7	Improving staff effectiveness and efficiency in order to meet the requirements of the new products	- Training middle management to apply successive planning Employees 50 % - Using IMC and Industrial Chamber funding services in order to train factory labourers in order to enhance their awareness with regards to quality management system 50%	0.15	100%	25%
8	Meeting Expense Budget	% of expense budget that covered without shortage	0.15	100%	97%
9	Increasing sales by 50% compared to 2009 actual sales	Percentage increase in sales in 2010 compared to 2009 actual sales	0.15	100%	66%

6.3.3 Scenario Four (increasing SC responsiveness)

As well as Scenario Three, Scenario Four is relevant when the analysis of financial performance results highlights revenue as the financial driver that most requires attention. However, in Scenario Four, the SCI indicates that the performance of SC processes to which responsiveness measures correspond register the poorest performance among all SC processes with regard to the performance rating scale. Therefore, the company's new strategic objective should focus on “increasing revenue”, particularly through increasing SC responsiveness. As a result, the appropriate supply chain operational strategy to align with the company's strategic financial priorities will be enhancing the processes to which responsiveness performance measures correspond. This consequently will lead to assignment of the highest priority weight at the top level of the SCOR hierarchy to responsiveness measures. The corresponding objectives and key performance indicators at the top level of the SCOR model are presented in table 6.5.

Table 6.5: The appropriate SC operational strategy and corresponding level 1 objectives with regard to Scenario Four

Strategic aim	**Level 1 objectives**	**Responsibilities**	**Key performance indicators at level 1 metrics**
Increasing SC responsiveness	Reducing the average actual number of days consistently achieved to fulfil customer orders by..... days.	Commercial department, Production department and Follow-up department	Order Fulfilment Cycle Time

Figure 6.3 summarises the actual performance of the bottled water company’s responsiveness measures in 2010. The performance rate of the order fulfilment cycle time was very good (***VG***). As shown at level 2, make and deliver cycle times registered very good performance rate; while the source cycle time performance rate was good.

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
RS									
Node : RS									
RS 1.1	Order Fulfillment Cycle Time	الدورة الزمنية اللازمة لإستيفاء الطلبيات	.2	1	.83		VG	.739	.613
RS 2.1	Source Cycle Time	الدورة الزمنية اللازمة لإتمام عمليات التوريد	.2	1	.18		G	.497	.089
RS 2.2	Make Cycle Time	الدورة الزمنية اللازمة لإتمام مراحل التصنيع	.2	1	.36		VG	.798	.287
RS 2.3	Deliver Cycle Time	الدورة الزمنية اللازمة لاتمام مراحل تسليم المنتج للعميل	.2	1	.46		VG	.79	.363

Figure 6.3: The aggregated performance of the bottled water company’s SC responsiveness measures

These results indicate that in order to increase SC responsiveness in the new accounting period, the company should focus on reducing the average time associated with source processes including: identify sources of supply cycle time, select supplier and negotiate cycle time, schedule product deliveries cycle time, receive product cycle time, verify product cycle time, transfer product cycle time and authorise supplier payment cycle time. Figure 6.4 illustrates level 3 metrics source cycle time sub measures that most need improvement: identifying sources of supply cycle time, selecting and negotiating with supplier cycle time and verifying product cycle time.

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
RS									
RS 3.1	Identify Sources of Supply Cycle Time	الفترة الزمنية اللازمة لتحديد مصادر التوريد	.2	1	.1		VP		
RS 3.2	Select Supplier and Negotiate Cycle Time	الفترة الزمنية اللازمة لأختيار المورد والتفاوض معه	.2	1	.11		VP		
RS 3.3	Schedule Product Deliveries Cycle Time	الفترة الزمنية اللازمة لوضع جداول أوامر التوريد لمستلزمات الإنتاج	.2	1	.19		VG	.716	.136
RS 3.4	Receive Product Cycle Time	الفترة الزمنية اللازمة لإستلام طلبيات مستلزمات الإنتاج الواردة	.2	1	.26		G	.544	.141
RS 3.5	Verify Product Cycle Time	الفترة الزمنية اللازمة لفحص طلبيات مستلزمات الإنتاج الواردة والتأكد من مطابقتها للمواصفات	.2	1	.15		P	.372	.056
RS 3.6	Transfer Product Cycle Time	الفترة الزمنية اللازمة لتخزين الطلبيات الواردة بمخزن مستلزمات الإنتاج	.2	1	.09		VG	.716	.064
RS 3.7	Authorize Supplier Payment Cycle Time	الفترة الزمنية اللازمة لإتمام الإجراءات الخاصة بسداد مستحقات الموردين	.2	1	.1		E	1	.1

Figure 6.4: The aggregated performance of the bottled water company’s SC source cycle time measures

6.3.4 <u>Scenario Five (managing SC assets)</u>

Scenario Five (managing SC assets) has been applied in the numerical example in chapter four. As illustrated in the numerical example, this scenario is relevant when the company’s short-term strategic financial objective is to improve its efficiency and the analysis of financial performance results highlights assets as the financial driver that most requires attention. In addition, the analysis of SCI indicates that SC processes to which asset management measures correspond register the poorest performance among all SC processes with respect to the performance rating scale. As a result, the relevant present path to enhance financial results will be "improving asset utilisation" particularly through managing SC assets. In this case, the most appropriate SC operational strategy is to focus on enhancing the processes to which asset management performance measures correspond and consequently, the highest priority weight at the top level of the SCOR hierarchy is assigned to asset management measures. The corresponding objectives, plan of action and key performance indicators at the top level of the SC have been previously presented in chapter four (see table 4.9).

The actual performance of the bottled water company's assets management measures in 2010 at different levels of the SCOR hierarchy is illustrated in figure 6.5.

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
AM									
Node : AM									
AM 1.1	Cash-to-Cash Cycle Time	الدورة الزمنية النقدية	.2	1	.44		VG	.686	.302
AM 1.2	Return on Supply Chain Fixed Assets	العائد على الأصول الثابتة بسلسلة الإمداد	.1	.15	.12	.06	VP	.2	.024
AM 1.3	Return on Working Capital	العائد على رأس المال العامل	.3	.6	.18	-.01	VP	.2	.036
AM 1.4	Capacity Utilization	الأستخدام الأمثل للطاقة الإستيعابية	.2	1	.26		VG	.623	.162
AM 2.1	Days Sales Outstanding	متوسط فترة التحصيل	77	57	.54	54	E	1	.54
AM 2.2	Inventory Days of Supply	متوسط فترة التخزين	26	16	.33	20	G	.6	.198
AM 2.3	Days Payable Outstanding	متوسط فترة السداد	30	44	.13	31	P	.4	.052
AM 2.4	Operating Rate	(نسبة التشغيل (معدل التشغيل	85	95	.22	58.629	VP	.2	.044
AM 2.5	Downtime	نسبة التوقف	.2	1	.38		VG	.681	.259
AM 2.6	% spoilage Material	نسبة الهالك من المواد الخام	3	1	.4	1.211	VG	.8	.32
AM 3.1	Scheduled Downtime	نسبة التوقف المخططه	.2	1	.69		VG	.8	.552
AM 3.2	Unscheduled Downtime	(نسبة التوقف الفجائية (الغير مخططه	.2	1	.31		G	.416	.129

Figure 6.5: The aggregated performance of the bottled water company's SC assets management

The company's cash to cash cycle time was fast with respect to the performance rating scale; however the rates of return on fixed assets and working capital were very poor and lower than the minimum acceptable rate.

The results also indicate that spoilage material percentage and downtime percentage were very good resulting in a very good rate of materials management and capacity utilisation. Although the company registered a very poor operating rate; the relatively low importance weight comparing to downtime percentage and spoilage material percentage does not result in a great impact on overall capacity utilisation performance.

According to these results, for better asset management in the new accounting period, the bottled water company should focus on increasing its ability to generate profit from assets employed in the business. On the other hand, giving the priority in the new period to enhance the operating rate can positively impact the rate of return on fixed assets as well as the capacity utilisation rate. As shown at level three, the unscheduled downtime percentage was good. Minimising the unscheduled downtime could be the first step towards enhancing the operating rate; and consequently increasing the rate of return on fixed assets and the capacity utilisation rate.

As presented at level 2, the days payable outstanding measure had a poor performance rate with respect to the performance rating scale. Improving this ratio can contribute to enhancing the rate of return on working capital and accelerating the cash to cash cycle time. The performance rate of inventory days of supply measure was extremely good; however since it has a relatively high importance weight; improving this ratio could have a greater impact on enhancing the rate of return on working capital and the cash to cash cycle time compared to days payable outstanding.

The above discussion illustrated five main alternative scenarios. For each scenario, the targeted financial outcome is identified (increasing profitability or improving efficiency). Then, the corresponding path to achieve this targeted financial outcome is determined (managing cost, increasing revenue, or improving asset utilisation) through assessing the contribution of each financial performance driver. Finally, the appropriate SC operational strategy is formulated (managing SC costs, increasing SC agility, improving SC reliability, increasing SC responsiveness or managing SC assets) based on the standard performance metrics of the SCOR model.

The actual performance of the bottled water company's SC operations in 2010 was analysed. For each SC performance measurement category (RL, RS, AG, CO, AM), the performance of sub measures at different levels of the SCOR hierarchy have been traced and analysed in order to identify performance measures which require improvement.

Table 6.6 presents SC performance measures that require improvement in each SC performance measurement category. Since each measure corresponds to specific processes in the SC, the relevant SC processes can be traced based on the SCOR model standard description of SC processes. Then, the corresponding objectives, plans of action and the responsible departments are identified.

Table 6.6: The bottled water company's SC performance measures that require improvement at each SC performance measurement category

Performance category	Performance measures need improvement
CO (Poor)	1. freight expense 2. material cost 3. direct sales expense 4. indirect costs related to making product 5. labour cost and direct marketing expense
RS (Very Good)	source cycle time, source cycle time sub measures that need improvement are: 1. identifying sources of supply cycle time 2. selecting and negotiating with supplier cycle time 3. verifying product cycle time

AG (Very Good)	1. upside SC flexibility 2. downside make adaptability and downside deliver adaptability 3. upside deliver adaptability
AM (Good)	1. return on SC fixed assets 2. return on working capital 3. the operating rate 4. unscheduled downtime 5. Inventory days of supply 6. days payable outstanding
RL (Very Good)	1. SC forecast accuracy 2. deliver return forecast accuracy

6.3.5 A systems view of the proposed scenario analysis approach

Different scenarios have been proposed to illustrate the most appropriate SC operational strategy with regard to the targeted financial results. However, it should be noted that these scenarios are not one-way scenarios as they can be operated in both directions. It is not necessary to start with an inappropriate financial performance outcome and then identify the related path to improve this outcome. A scenario might start with identifying a path to achieve a specific targeted financial outcome (see figure 6.1).

According to the systems view problem-solving model developed by Mitroff et al. (1974), the proposed scenario approach can be operated in two directions given two different possible loops: (II, III, IV and I) and (I, II, III and IV) (see figure 3.2).

Figure 6.6 shows how a systems point of view can be adapted to carry out the proposed scenario approach in two possible directions. The first direction starts with five main conceptual alternative scenarios (II). Then, a scientific model is formed to determine the relevant scenario that will be modelled and implemented (III). At this stage, the focus area for enhancing the financial performance is identified through assessing the contribution of each financial performance driver (revenue, cost and asset) and tracing their related SC operations. Then, SC operations that need improvement and their corresponding performance measures can be identified, and the relevant scenario is determined (managing SC costs, increasing SC agility, improving SC reliability, increasing SC responsiveness or managing SC assets). Consequently, the appropriate SC operational strategy is formulated (IV) and implemented to achieve the targeted financial outcomes (I).

As illustrated in figure 6.6, the second direction starts with an inappropriate financial performance result (I). In this case, the relevant scenario is constructed theoretically based on the recognition of a real problem situation (II). Once the relevant scenario is identified, the scientific model can be formed through tracing the source of poor performance in terms of relevant SC operations, then the corresponding SC performance measures can be determined based on the SCOR model standard performance metrics (III). Finally, the appropriate SC operational strategy is formulated to improve the performance of relevant SC operations, and consequently enhance finacial performance results (IV). The next section discusses in detail the significance of key findings in relation to previous research.

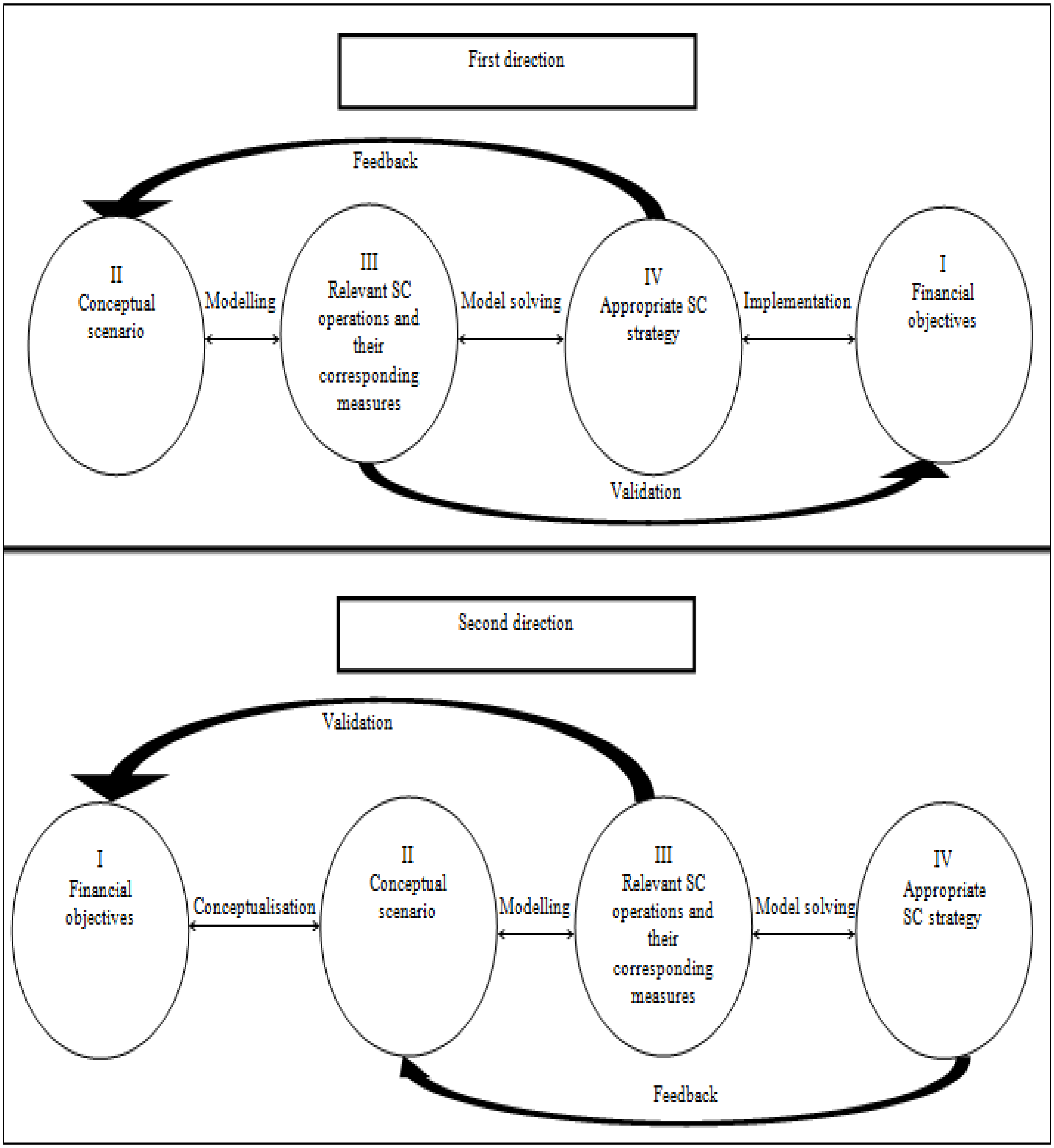


Figure 6.6: Systems view of the scenario analysis

6.4 Discussion of key findings

1- The proposed SCOR FAHP technique provided an effective tool to analyse, assess and improve the performance of SC operations.

As the result of extensive review, synthesis and analysis of published literature, it was found that a well-designed integrated SC performance measurement system is essential for companies to compete in the today's business environment. An integrated SC performance measurement system can be utilised as a strategic tool for achieving the targeted objectives and goals through evaluating, managing and continuously controlling the entire set of SC operations (see section 2.3).

The proposed SCOR FAHP technique proved to be an integrated SC performance measurement system that can be employed to increase the effectiveness and the efficiency of SC operations in meeting SC goals. It provided integrated performance measurement metrics to measure SC operations' performance from different perspectives (reliability, responsiveness, agility, cost and asset management) based on the SCOR model's standard performance metrics. Since each SC performance measurement attribute has a weighted rate and corresponds to specific processes in the SC, companies can apply this technique to identify core competence SC processes and those processes that need improvement.

The review also revealed that understanding and analysing the characteristics, the structure and the strategy of the targeted supply chain are essential primary steps to develop an effective SC performance measurement system, on which the appropriate SC framework can be selected (see section 2.4.1).

The proposed SCOR FAHP technique provided a framework to assess the whole supply chain system through identifying the characteristics, the structure and the strategy of the targeted supply chain, then mapping and evaluating the processes in the entire supply chain based on the SCOR model's standard description of SC processes and its corresponding standard performance metrics.

Several SC performance measurement frameworks have been developed to guide the analysis and the evaluation of the supply chain performance. The two broadly used frameworks are the Global Supply Chain Framework (GSCF) and the Supply Chain Operations Reference (SCOR) Model. The SCOR and the GSCF models provide standardised business processes frameworks to accomplish SCM integration within organisations and across the SC. Successful implementation of intra-organisational integration is considered a pre-requisite for companies to adopt and implement SCM or inter-organisational integration (see section 2.4.2).

Incorporating the SCOR model in the proposed SCOR FAHP technique helped accomplish successful implementation of intra-organisational integration. Although the bottled water company has a traditional functional organisational structure, cross functional integration has been accomplished in the company from the top level to the implementation levels after implementing the SCOR FAHP technique.

In addition the literature revealed a need for an adequate SC benchmarking method that can identify SC performance improvement opportunities through determining the relative importance of performance measures and then aggregating them into a single index of overall performance from which a company can compare its SC performance with other industry members (see section 2.4.3).

Incorporating FAHP in the SCOR model for measuring SC performance can be employed as an effective benchmarking method through determining the degree to which SC performance metrics contribute towards the success of a particular strategy. Based on FAHP technique, the weighted rates (WR) of all SC performance measures can be calculated and then aggregated throughout the hierarchy of SC performance measures to determine the company's supply chain performance index (SCI) which reveals the overall SC operations' performance.

2- The developed performance measurement method to link SC operations' performance to the company's strategic financial objectives showed that managing the performance of SC operations can have a significant impact on enhancing a company's overall financial performance.

The review highlighted that more awareness should be directed towards the connection between SC operational strategy and financial performance improvements. Designing and implementing a SC performance measurement system should be tailored to align with the company's strategic financial objectives. Understanding the interrelationships between SC performance metrics and the overall metrics used to measure the company's financial performance is essential to link SC processes' performance to the company's strategic financial goal through translating the performance of SC day to day operations into financial targets (see section 2.5).

The developed performance measurement method to link SC operations' performance to the company's strategic financial objectives provided an effective SCM tool to evaluate current SC operational strategy and then formulate the new SC operational strategy based on the priorities of the financial performance targets.

The DS/AHP model as a multi-criteria decision-making model utilised to link SC operations' performance to the company's strategic financial objectives in the short-term and to evaluate its impact on maximising profit - as the company's primary long-term financial goal - through determining the importance weights of SC operations' performance measures with respect to the priorities of the company's financial performance.

3- The developed research methodology provided an integrated modelling approach for design and analysis of supply chain system.

As discussed earlier, the primary long-term financial goal of the company can be accomplished through translating it into meaningful short-term performance objectives that can be measured and monitored. The literature showed that the main challenge for many companies is how to link SC processes and activities with their focus on day to day operations to the main financial goal. Previous studies suggested that analysing the interrelationships between SC performance metrics and the financial performance metrics used to measure the company's overall performance can help linking SC processes' performance to the company's strategic financial goal (see section 2.5).

However, the literature revealed that the existing modelling approaches for design and analysis of supply chain system cannot fully demonstrate the interrelationships between SC performance measures and how these interrelationships affect formulating strategies (see section 2.3.4). The prioritisation and choice of relevant SC metrics and measures were highlighted in literature as an important aspect that can contribute to developing an appropriate SCPMS aligning SC performance with the organisational goals. Assigning relative importance weights of SC performance measures with respect to the organisational goals allows tracing the contribution of each SC performance measure to the overall performance, and consequently identifying SC performance measures that need improvement upon which the suitable SC strategy can be formulated (see section 2.3.3).

The proposed SCOR FAHP technique focused on the modelling of SC operational processes in order to contribute to improvement in the company's overall financial performance. Utilising the FAHP technique provided a multi-criteria decision making approach to deal with the prioritisation and choice of SC metrics and measures. It created a holistic view of analysing SC performance through determining the relative importance of performance measures and then aggregating them into a single index revealing the overall SC performance.

The operational focus of the SCOR model allowed translating the entire SC processes - with their focus on day to day operations- into financial targets through aligning the company's SC resources and goals with the strategic financial objectives. The hierarchy of the SCOR model helped to disaggregate the overall SC performance to different measures and different levels of detail in order to trace the contribution of each SC performance measure to the overall performance, and consequently identify the SC processes that need improvement.

The developed performance measurement method linked SC operations' performance to the company's strategic financial objectives. The method allowed translating financial performance objectives with their strategic focus into specific action plans for performance enhancement. On the other hand, SC performance measures with their focus on day to day operations were translated into meaningful financial targets that can contribute to accomplishing the company's overall financial objectives.

4- Conducting a case study of an Egyptian bottled water company demonstrated the applicability of the research procedure in the manufacturing sector and empirically validated the research proposition.

Although previous studies confirmed the positive effects of SCM on an organisation's performance, the literature review revealed a lack of empirical studies for the development and validation of the theory of SCM execution within a company (see section 2.6). The review of empirical research in OM field highlighted the ability of case study research method to investigate the phenomenon in its context. Since the case study research method uses multiple data sources based on both quantitative and qualitative approaches, a holistic view as well as in depth information about the investigated phenomenon can be recognised (see section 3.4).

Five major phases were carried out in the case study and illustrated in detail in chapter five in order to implement the created research framework and demonstrate its applicability in a real life context. Financial performance results for the bottled water company were evaluated and analysed using Du Pont ratio analysis in order to identify financial performance drivers that require improvement (revenue, cost and/or assets). Then, the focus areas for enhancing the financial performance in terms of relevant SC operations were traced and their corresponding SC performance measures were identified based on the SCOR FAHP technique. Finally, the appropriate SC operational strategy was formulated in order to enhance and control the performance of relevant SC operations and consequently the company's overall financial performance. The results showed improvements in the financial performance after applying the suggested SC operational strategy.

5- The designed SCM KPIs system provided a practical tool to evaluate, monitor and control SC operations' performance.

Literature revealed that an efficient and effective performance measurement system should be presented in a clear and consistent format in order to provide timely and accurate feedback about the organisation performance (see section 2.2). As discussed earlier, developing performance measurement system based on DBMS environment can provide flexible representation and aggregation of the performance measures. In addition, it enables demonstrating the interrelationships between these measures which gives the opportunity to illustrate performance results in various ways (see section 5.5.1).

The proposed SCM KPIs system proved to be a practical tool evaluating, monitoring and controlling SC operations' performance. The system was designed based on SQL database utilising the proposed SCOR FAHP technique which enabled the real application of the developed research methodology and allowed flexible representation and aggregation of SC operations' performance throughout the hierarchy of SC from the implementation levels to the top level. It helped to establish links between performance measures which facilitate analysis of SC performance from different perspectives. The feedback from the bottled water company showed that the implementation of the designed SCM KPIs system allowed the company to identify SC processes that need improvement and to focus on the SC performance's problematic areas (see section 5.6.3). The implementation of this system provided a detailed evaluation and a continuous feedback on the company's SC performance and helped to decide the necessary corrective actions through calculating the two indexes (SCI and SCFLI).

6- The scenario analysis approach illustrated how the developed research procedure can be applied in various possible financial performance contexts.

The literature highlighted Mitroff et al.'s (1974) conceptual model of the operations research process. The model adopted general systems theory with a holistic point of view upon which OR can be understood and effectively applied to cover diverse research styles (see section 3.3).

Five scenarios were proposed to illustrate the applicability of developed research methodology under various possible financial performance contexts. However, these five scenarios presented the main alternative scenarios based on the SCOR model five main performance categories (i.e.

reliability, responsiveness, flexibility, cost and asset management). More scenarios can be created based on the different possible set of combinations of these five main alternatives.

The systems view of the proposed scenario analysis approach reflected the integration between SC operational strategy and the company's overall financial strategy. The alternative scenarios were utilised to identify the most appropriate SC operational strategy with regard to targeted financial objectives and their relevant SC processes. According to the systems view problem-solving model proposed by Mitroff et al. (1974), the scenario analysis approach can be operated in two directions given two different possible loops. A company can formulate SC operational strategy to achieve targeted strategic financial objectives or it can start with an inappropriate financial performance and then formulate the corresponding SC operational strategy to enhance it.

6.5 Conclusion

The research findings proved to be in line with previous studies and the research proposition derived from these studies. The findings revealed that SC operational strategy and the company's overall financial strategy can be aligned through understanding the link between SC performance metrics and financial performance metrics. Financial performance targets with their strategic focus should be translated into specific action plans. The priorities of financial performance measures can be identified based on these action plans. Accordingly, the subsequent SC activities required to carry out the action plans are determined. Finally, the appropriate SC operational strategy is formulated to improve the performance of these activities. On the other hand, SC performance measures with their focus on day to day operations should be translated into meaningful financial targets that can contribute to accomplishing the company's overall financial goal (see figure 6.7).

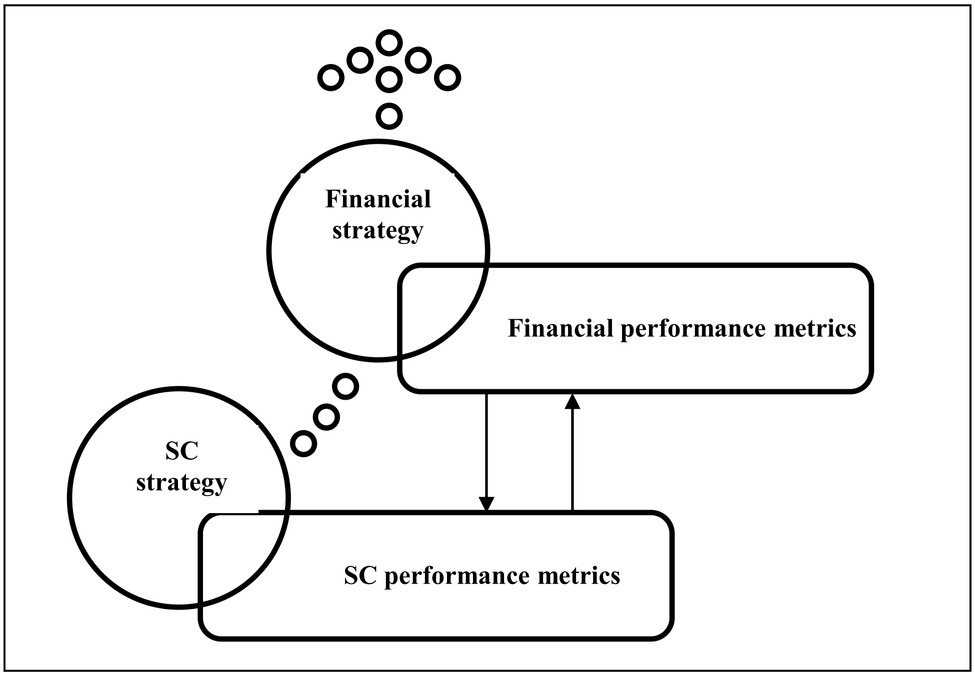


Figure 6.7: The integration between SC operational strategy and the company's financial strategy

Scenario analyses were undertaken to illustrate how this approach can be applied under various possible financial performance scenarios. Based on this approach, companies can formulate appropriate SC operational strategy by considering the targeted financial outcome and proposing the subsequent plans of action to enhance and control the performance of the relevant SC operations. According to this approach, the company’s financial performance results are analysed using Du Pont ratio analysis in order to determine the relevant scenario. Then, the corresponding SC performance measures are identified and the appropriate SC operational strategy is formulated based on the standard performance metrics of the SCOR model. Finally, financial performance results are analysed again after implementing the formulated SC operational strategy in order to evaluate its impact on achieving the company’s targeted financial outcome. The applied framework of the research method is presented in figure 6.8. In the next (and last) chapter, the overall conclusions from this research and recommendations for future work will be discussed.

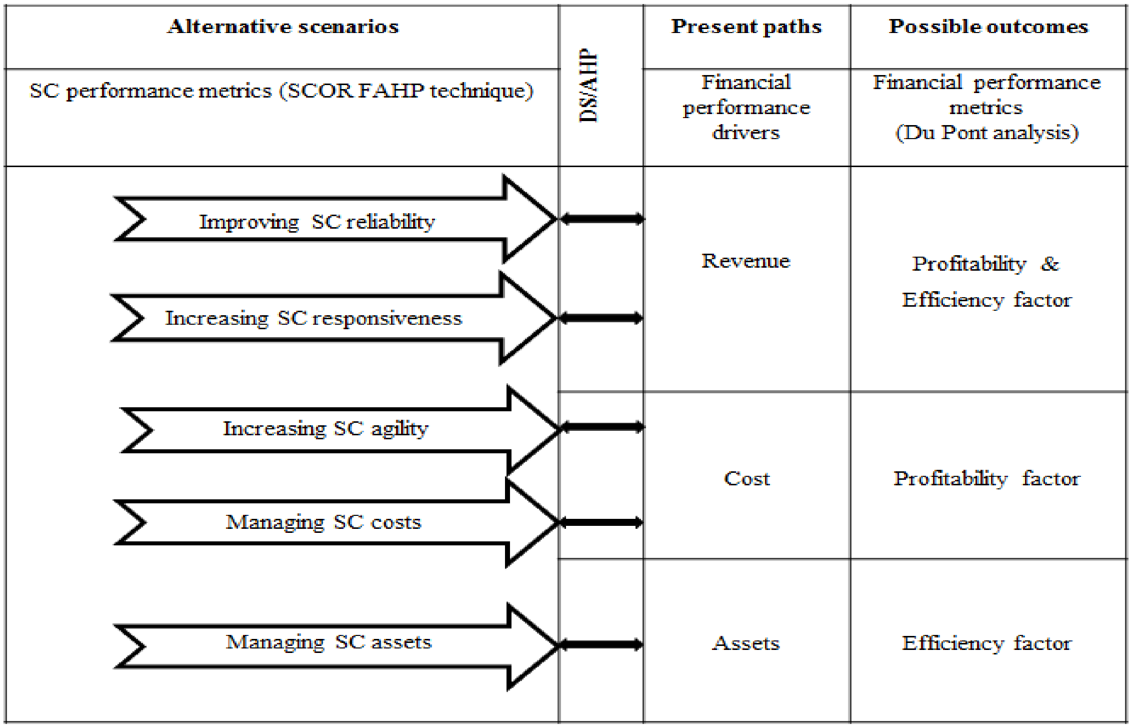


Figure 6.8: The applied framework of the research method

CHAPTER SEVEN - CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

7.1 Introduction

This chapter presents the overall conclusions derived from this research, followed by recommendations for future work. It starts by discussing the realisation of the research aim and objectives through reviewing the research processes which have been undertaken to address these objectives. Then, it illustrates the research contribution to theory and practice. Finally, the limitations of the study are identified, upon which areas for further research are suggested.

The remainder of this chapter is organised as follows. Section 7.2 evaluates the realisation of the research aim and objectives. The research contributions to knowledge are discussed in section 7.3. Section 7.4 presents the research limitations. Finally, section 7.5 suggests recommendations for future work through which this research could be further developed.

7.2 Realisation of the research aim and objectives

The aim of this research was to develop a procedure to enhance the financial performance of manufacturing companies through managing performance of the supply chain operations (section 1.2). To achieve this aim, the research methodology stated in section 1.3 has successfully addressed the six research objectives.

Research objective 1: To review the literature concerning supply chain performance and its link to overall financial performance.

This objective has been addressed by a review of published research concerning supply chain performance and its link to overall financial performance. The review of literature revealed that traditional financial measures are unable to reflect all the aspects essential to business success. It indicated a gap in the previous research to create fully integrated SC performance measurement systems that can align with the overall business strategy and reflect various aspects of organisational performance.

A limited number of studies have been conducted to investigate the link between SCM practices and financial performance improvements. The literature highlighted the need for a balanced performance measurement framework combining financial and non-financial sets of metrics to manage the performance of different supply chain functional areas and reflect the financial impact of supply chain performance on the company's overall financial performance. This consequently leads to the need for applied methodology linking supply chain operations' performance to the strategic financial objectives in order to contribute to enhancing the overall financial performance.

Research objective 2: To propose a technique to analyse, assess and improve the performance of supply chain operations.

On the basis of insights developed from the review of published research on the design and implementation of performance measurement systems and the application of fuzzy logic in a supply chain context, a SCOR FAHP technique has been proposed to analyse, assess and improve the performance of SC operations. The proposed technique was developed through: (i) identifying the main processes and sub processes in the supply chain and mapping these processes to SCOR model's standard description of SC processes, (ii) identifying the corresponding performance measurement attributes for the previously mapped processes based on the SCOR model standard performance metrics, (iii) determining the relative importance weight of each attribute using a fuzzy pair-wise comparison, (iv) assigning a performance rate for each attribute using performance rating scale. (v) consequently, calculating the weighted rate for each attribute by multiplying the importance weight of each attribute by its performance rate. (vi) finally, aggregating the weighted rate for each attribute across all SC performance measurement attributes using the weighted average aggregation method in order to determine the performance index of the company's supply chain. The detailed procedures of developing the technique were illustrated in chapter four.

The SCOR FAHP technique has been applied successfully in the case study company. The technique was found to be an effective tool to analyse, assess and improve the performance of SC operations. It was also found that this technique can be employed to manage the effectiveness and efficiency of supply chain operations in meeting supply chain goals through identifying core competence SC operations and those operations that need improvement in order to contribute to an overall improvement in the company's performance.

Research objective 3: To develop a performance measurement method to link supply chain operations' performance to the company's strategic financial objectives.

A conceptual framework has been proposed to link SC operations' performance to the company's strategic financial objectives. The DS/AHP model was used as a basis to determine the importance weights of SC operations' performance measures with respect to the priorities of the company's financial strategy. To test the extent to which SC operations' performance is linked to the company's short-term strategic financial objectives, a SCFLI was developed. This index was used to provide more control over the identification of daily SC operations as it enables the tracing of SC processes that need improvement, and consequently identify their related performance indicators for better SCM. A detailed explanation of the developed method was provided in chapter four. A numerical example was illustrated to give a holistic view of how this method can be implemented in a complex real life context.

The method has then been applied successfully in the case study company. It proved to be an effective SCM tool to connect SC operations' performance to the company's short-term strategic financial objectives through evaluating current SC operational strategy and then formulating the new SC operational strategy based on financial performance priorities.

Research objective 4: To design a software application system to measure and evaluate the impact of supply chain operations' performance on enhancing the company's overall financial performance.

Once the research framework was formulated through achieving the previous two objectives, SW application system, named Supply Chain Management Key Performance Indicators (SCM KPIs) was designed to enable the real application of this framework. It utilised the proposed SCOR FAHP technique for the purpose of managing SC operations' performance and evaluating its impact on enhancing overall financial performance.

SQL database was used to develop the SW application system based upon four major stages namely; setting up the application in SQL, enabling the departments to enter daily SC operations data, aggregating SC operations annual performance and calculating the SC index. This SW application calculates two indexes: SCI to reveal SC operations performance and SCFLI to measure and evaluate the impact of supply chain operations' performance on enhancing the overall financial performance.

Research objective 5: To demonstrate the applicability of the proposed procedure through conducting a case study of an Egyptian manufacturing company.

A case study of a manufacturing company (an Egyptian bottled water company) was conducted to demonstrate the applicability of the proposed research procedure and to test the prior developed theoretical proposition. The proposed procedure was applied to the case study company (i.e. the bottled water company) following five major phases: case design and preparation for data collection, introductory phase, establishing the SCOR FAHP technique, implementation phase and data analysis phase.

In the first phase, the Egyptian bottled water sector was described and analysed, then case study nominations were screened and the appropriate case was selected; finally the case study protocol was developed. The introductory phase provided an overview of the case study company's internal and external environment, based on which the company's SWOT analysis was drawn. In addition, this phase identified and analysed the characteristics, the structure and the strategy of the bottled water company's supply chain. In the third phase, the proposed SCOR FAHP technique was established for the case study company. First, the main processes and sub processes of the bottled water company's SC were identified and mapped to SCOR model's standard descriptions of SC processes. Then, the corresponding performance measurement attributes for the previously mapped processes were determined and prioritised using the FAHP technique. Finally, a performance rating scale for SC performance measurement attributes was established to calculate the SC index.

During the implementation phase, the performance of the company's SC processes was collected for the year ended December 31st 2010 on a daily or monthly basis according to the process using the SW application system. This data was aggregated at the end of the year to establish an annual measure in terms of SCI. Then, the bottled water company's financial performance during this period was evaluated and the priorities of financial performance factors were determined. Finally based on these priorities, the relative importance weights of the five main SC performance measures were calculated and the appropriate SC operational strategy was formulated. In the analysis phase, data collected during the implementation phase was analysed to explore the impact of managing supply chain operations using the proposed procedure on enhancing the company‘s financial performance. The case study's findings showed improvements in the financial performance of the bottled water company after applying the suggested SC operational strategy.

Adopting a case study research approach provided in depth information about the bottled water company and allowed a lot of detail to be collected based on a mix of quantitative and qualitative evidences, which would not normally be easily obtained by other research approaches. Conducting the case study of the bottled water company enabled implementing the proposed research procedure in a complex real life context, which helped to understand the research phenomenon in a real life context and challenging the research proposition through real life situations and issues.

Research objective 6: To propose a scenario analysis approach in order to illustrate how the developed research method can be applied according to various possible financial performance results.

Five main alternative scenarios were proposed in chapter six to illustrate the most appropriate SC operational strategy with regard to targeted financial results. For each scenario, the targeted financial outcome was identified. Then, the corresponding path to achieve this targeted financial outcome was determined through assessing the contribution of each financial performance driver. Finally, the appropriate SC operational strategy was formulated based on the standard performance metrics of the SCOR model.

The five scenarios were illustrated numerically based on the actual performance of the bottled water company's SC operations in 2010. For each scenario, the performance of sub measures at different levels of SCOR hierarchy were traced and analysed in order to identify performance measures that require improvement and their relevant SC processes. Consequently, for each scenario the corresponding objectives, plans of action and the responsible departments were identified.

The previous discussion showed how the research methodology and processes were undertaken to achieve the research objectives; and as a result the research aim was realised. In the next section, the research contributions to theory and practice are presented.

7.3 Contributions to Knowledge

This research provides an original contribution to knowledge by creating a framework linking SC operations' performance to the company's strategic financial objectives through focusing on the performance of the relevant SC operations and formulating the appropriate SC operational strategy to enhance it. This framework can be used as a strategic performance management tool to increase the effectiveness and the efficiency of a company's SC operational strategy in meeting targeted financial performance results and to contribute to the overall improvement in the company's performance.

The research brings together concepts from the areas of performance measurement, supply chain management, financial performance measurement, supply chain financial linkage and the multicriteria decision making approaches in order to develop a procedure to enhance the company's financial performance in the manufacturing sector through managing the performance of SC operations. Applying this procedure allows companies to control and have visibility of their entire set of operations through linking SC operations' performance with financial performance results.

Another contribution of this research is that it proposes a SCOR FAHP technique to manage SC performance. The proposed technique provides an effective tool to analyse, assess and improve the performance of SC operations through quantifying SC measurement criteria, environmental uncertainty and subjective judgements of SC performance evaluators. Applying this technique allows organisations to manage the performance of supply chain operations in meeting supply chain goals and to contribute to overall improvement in the company's performance.

This research is also a contribution in that it develops a method to align supply chain operational strategy with the company's financial strategy. Applying this method enables companies to formulate the appropriate supply chain operational strategy based on the priorities of the financial performance factors. Since the financial performance evaluation reflects the contribution of each of the financial performance factors and highlights factors that need improvement, developing a supply chain operational strategy with respect to the priorities of these factors can contribute to enhancing the overall financial performance.

In addition, the research designs a SW application system to evaluate, monitor and control SC operations' performance through calculating two indexes (SCI and SCFLI). The analysis of these indexes provides continuous feedback on SC performance and allows tracing SC processes that need improvement resulting in greater control over daily SC operations.

Moreover, the developed scenario analysis approach can help companies to formulate the appropriate SC operational strategy by considering the targeted financial outcome and proposing the subsequent plans of action to enhance and control the performance of the relevant SC operations.

The research and the practical implications of this study are summarised in table 7.1.

Table 7.1: The research and the practical implications

Research value	Research implication	Practical implication
Proposing SCOR FAHP technique	Analysing, assessing, and improving the performance of SC operations. This technique provides an effective tool to manage and quantify SC operations' performance through quantifying: SC measurement criteria, environmental uncertainty and subjective judgements of SC performance evaluators.	According to this technique, each SC performance measurement attribute has a weighted rate and corresponds to specific processes in the SC which enables companies to identify processes that need improvement. Applying this technique allows organisations to manage the effectiveness and the efficiency of supply chain operations in meeting supply chain goals and to contribute to overall improvement in the company's financial performance.
Developing a performance measurement method	Linking SC operations' performance to the company's strategic financial objectives through demonstrating and utilising the relationship between SC operations' performance and the company's financial performance using DS/AHP model.	The developed method allows evaluating, monitoring and controlling SC operations' performance in order to enhance SC performance for better alignment with the company's financial strategy.
Designing SQL SW application system	Evaluating supply chain operations' performance and determining its significant impact on enhancing the overall financial performance through calculating two indexes: -SCI with its operational levels to evaluate SC operations' performance. -SCFLI with its strategic priorities to reveal the extent to which SC operations' performance is linked to the company's short term strategic financial objectives.	This SW application provides continuous feedback on supply chain performance and helps to decide the necessary corrective actions through calculating the two indexes. Analysing the indexes' offers opportunities for detailed evaluation of SC operations' performance and enables companies to trace SC processes that need improvement resulting in more control over daily SC operations.
Developing scenario analysis approach	Illustrating how SC operational strategy can be linked to a company's financial performance according to various possible financial performance results.	This approach helps companies to formulate the appropriate SC operational strategy by considering the targeted financial outcome and proposing the subsequent plans of action to enhance and control the performance of the relevant SC operations.

7.4 Research limitations

While this research has provided a valuable contribution to knowledge as illustrated in the previous section, there are some limitations regarding the application of the research procedure on the case study company:

1- The research procedure was applied to the case study company for only one accounting period (the financial year ended December 31st 2010). The company's supply chain and financial data has been collected and entered into the SW application system for the whole year ended December 31st 2010 and for the month ended January 31st 2011 till 24th January. At the end of January 2011, the Egyptian revolution took place. Due to the instability resulting from this revolution (see section 5.2.1); the manufacturing process in the bottled water company was halted until the beginning of April 2012. As a result, data analysis and results are based only on the data collected during the financial year ended December 31st 2010.

2- The access to the case study company was only for evaluating the current situation and proposing suggestions for improvement. The researcher was not able to apply the newly proposed SC operational strategy and measure its impact on enhancing the overall financial performance. The research procedure was applied to the case study only for the phase of evaluating and analysing current SC operations' performance, while the phase of improving the performance of SC operations and measuring its impact on enhancing the overall financial performance was not applied to the case study company.

SC operations' performance was measured and analysed through calculating the SCI. Also SCFLI was calculated to measure and evaluate the extent to which SC operations' performance was aligned with the financial strategy. Based on these results, the focus area for enhancing the financial performance was determined, and consequently the relevant SC processes that need improvement were identified and the most suitable corresponding SC operational strategy was suggested.

However, the researcher was not permitted to implement the suggested SC operational strategy and as a result, the researcher was not able to investigate its impact on improving SC operations' performance and the company's overall financial performance.

To overcome these limitations, the current real situation of the bottled water company was extended numerically. The researcher assumed that the suggested SC operational strategy would be applied in order to demonstrate how improving the relevant SC operations could influence the targeted financial results after a financial year under three different conditions (optimistic, normal and pessimistic). In addition, a scenario analysis approach was undertaken using five main alternative scenarios in order to explore how this procedure could be applied with regard to various possible financial results.

3- As illustrated in the case study company, the aim of SC operational strategy was enhancing the processes to which cost performance measures correspond assuming that all other variables would not change and remain constant. However, companies' objectives are not mutually exclusive. SC operational strategy may include a number of conflicting aims and achieving one of the aims may cause other variables to move into undesirable status.

4- The research framework did not consider measures for the environmental categories. It focused only on linking financial and operational measures in order to identify possible practices to achieve the strategic financial objectives. The research proposed performance measurement system incorporating financial and operational performance metrics, while it did not address the environmental measures to be integrated into the proposed system.

5- The research focused on demonstrating and utilising the supply chain-financial performance link within a company. The research framework linked the performance of the entire SC operations with business strategy. A vertical analysis of this relationship within the bottled water company was done from the top level to the implementation levels. However, the current study did not consider upstream and downstream integration with other members in the SC as an important element of adopting a successful manufacturing strategy.

In the next section, recommendations for future research are suggested to address the limitations discussed in this section.

7.5 Recommendations for future work

1- Given the strategic, long-term orientation of the research procedure and the low probability, high impact event of the Egyptian revolution, practical implementation of the whole research procedure on the case study was not feasible over the time scale of this research. It is therefore desirable that a long-term application be conducted in an appropriate manufacturing company. Future research should consider collecting data for more than one financial year so as to investigate the impact of implementing the suggested SC operational strategy on improving SC operations' performance and enhancing the overall financial performance.

2- In addition, the research procedure developed was applied to only one case study company in the Egyptian bottled water sector. Further work should investigate and compare the results from several companies in different sectors of manufacturers in different locations. The research provides a standard procedure based on standardised SC performance metrics and financial performance metrics. This procedure can be repeated in any bottled water company up to level five process details with minor modifications as there are limited variations in the manufacturing processes of bottled water from one company to another. Also since the SCOR model provides standard descriptions of SC processes and standard metrics to measure the performance of these processes up to level three (the implementation level), the research procedure can be generalised to be applicable in any manufacturing company from any other sector to level three of process details.

3- In a further refinement of the proposed framework, more complex decision variables and multiple objectives can be integrated.

4- Further research can extend the current research framework to achieve the operational, financial and environmental SC performance objectives by considering measures for the environmental categories as well as the traditional financial and operational measures. As a suggestion for future work, the current proposed SC performance measurement system can be further developed by employing the methodology suggested by Olugu and Wong (2009) along with Bai et al.'s (2012) model - discussed in the literature review chapter- in order to quantitatively present and integrate the environmental measures. The model introduced by Bai et al. (2012) based on the SCOR model can help to propose performance measures that cover both traditional business and environmental measurements, while the fuzzy logic methodology suggested by Olugu and Wong (2009) can be utilised to quantify and integrate environmental measures with traditional measures (see section 2.3.2).

5- The research also suggests that the developed framework can be modified to adapt to the service sector. The SCOR model is more applicable to a manufacturing context than a service context as it provides standard description of SC processes and the relationship among these processes till level three of processes details (the process element level). Services vary and lack common features which create difficulties to standardise services supply chains' processes based on SCOR model. Comparing to the SCOR model, the structure of the GSCF model could be adopted to construct a framework for the key supply chain processes in a service context (Ellram et al., 2004). Accordingly, it is suggested as a further development of this research to incorporate the GSCF model instead of the SCOR model in the developed framework so it can be applied to the service sector.

6- Further refinement of this research should consider inter-organisational integration through horizontally linking internal SC processes to external suppliers and customers. As a suggestion for future research, the research framework can be extended horizontally by incorporating the GSCF model to align SC operational strategy with other members across the SC, and consequently investigating the supply chain-financial performance link across the SC network structure including all members with whom the focal company interacts directly or indirectly from the point of origin to the point of consumption (see section 2.4.2).

In summary, this research tackled an important area in the field of supply chain management through focusing on studying the relationships between SCM practices and financial performance improvements. The research study makes an original contribution in the direction of linking SC performance to a company's financial performance. A framework was created and implemented to link SC processes' performance to a company's strategic financial objectives.

The framework demonstrated how the implementation of the proposed SCOR FAHP technique together with the designed SW application system (SCM KPIs) based upon five main alternative scenarios can lead to an improvement in the SC operations' performance. Then, the developed performance measurement method is applied using the DS/AHP model in order to link SC performance metrics to the company’s financial performance metrics as an intermediate step (present path) towards achieving the targeted financial objectives (see figure 6.8). The research presented suggestions for future work to overcome the limitations encountered in this study. It also suggested recommendations for further research in order to encourage other researchers to engage in more studies in the area of supply chain-financial performance link.

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APPENDIX 1- Case study protocol

<u>Case study protocol</u>

1- An Overview of the Study

I am interested in the relationship between supply chain operations' performance and an organisation financial performance in the manufacturing sector. The research proposition to be investigated is **"Utilising the relationship between a company's SC operations performance and its financial performance can allow the company to develop a procedure to identify and implement SCM practices by which financial performance can improve"**.

This research proposition focuses on the relationship between SCM practices and financial performance improvements. The study proposition is derived from previous studies in the area of SCM which confirmed the positive effects of SCM on an organisation's performance.

To test this theoretical proposition, a framework is created and implemented to align supply chain operational strategy and the company's overall strategy through linking supply chain operations' performance to the company's financial performance in the manufacturing sector. This framework aims to:

- Propose a technique to analyse, assess and improve the performance of SC operations.
- Develop a performance measurement method to link SC operations' performance to a company's financial strategy and then examine the impact of managing supply chain operations' performance on enhancing the financial performance of a company.

The research proposes a technique which incorporates the fuzzy analytic hierarchy process method (FAHP) and the supply chain operations reference-model (SCOR) to analyse, assess and improve the performance of SC operations. This technique allows organisations to manage the effectiveness and efficiency of supply chain operations in meeting supply chain goals and to contribute to overall improvement in the company's performance through identifying SC processes that are working well and areas where the SC might need improvement.

The research also develops a method which links SC operations' performance to the company's short-term strategic financial objectives using the DS/AHP model. The developed method enables companies to formulate SC strategies for optimising short-term strategic financial objectives through linking such strategies to the focus area of enhancing the financial performance.

The research designs and implements SW application system based on SQL database which enables the real application of the research method through calculating two indexes:

- Supply chain index (SCI) with its operational levels to evaluate SC operations' performance.
- Supply chain financial link index (SCFLI) with its strategic priorities to reveal the extent to which SC operations' performance is linked to the company's short term strategic financial objectives.

This SW application provides continuous feedback on supply chain performance and helps to decide the necessary corrective actions through calculating the two indexes. Analysing the indexes offers opportunities for detailed evaluation of SC operations' performance and enables companies to trace SC processes that need improvement resulting in more control on the daily SC operations.

To demonstrate the applicability of the research method, a case study of an Egyptian bottled water company is conducted.

I believe this proposition to be true because previous research indicated that the real competition is not company against company but supply chain (SC) against supply chain (1). Measuring the performance of supply chains can facilitate the integration between supply chain partners and contribute to decision making in supply chain management (SCM), especially in redesigning business goals and strategies through assessing the current SC operations' performance in order to identify core competence operations and those operations which need improvement (2).

Managers at different levels should be aware of the connection between supply chain performance and the company's financial strategy, and how the company's daily actions can impact the overall financial performance. Presutti Jr. and Mawhinney (2007) stated that 70 percentage or more of manufacturing companies' expenditures are on supply chain-related activities, which highlights the potential impact of an effectively managed supply chain in contributing to overall improvement in financial performance (3). The impact of SCM on a company's performance has been discussed by many researchers; however few studies have been conducted to find the links between SCM practices and financial performance improvements (4). Toyli et al. (2008) stated that supply chain performance and the organisation's financial performance have been widely studied but limited empirical affirmation of their relationship has been presented (5).

Although previous studies in the area of SCM confirmed the positive effects of SCM on an organisation's performance, empirical evidence to develop a theoretical base for the establishment and execution of SCM within a company is still lacking (6). Moreover, supply chain management is not yet in the forefront of determining the financial performance which highlights a need for an applied framework capturing the critical link between an organisation's SC operational strategy and its business performance. Understanding the link between SCM practices and financial performance improvement could help companies to gain competitive advantage through linking SC performance to the company's targeted financial objectives.

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2- Data Collection Procedures

The bottled water company has been selected to serve as a case study for this research. To gain access to the company, an entry letter has been submitted to it. After the acceptance of this letter, a confidentiality agreement, also known as nondisclosure agreement (NDA), was prepared and signed to protect any type of confidential information from public disclosure.

The following table illustrates a schedule of the data collection activities that are expected to be accomplished within different research phases:

Introductory phase		
Time	**Targeted output**	**Data collection method/ model /technique**
March 2009	Description of the Egyptian bottled water industry in terms of: different brands and the market's major players, the competitive environment and the key factors influencing the market.	1- Online references, periodicals and specialised journals
March 2009	Analysis of the overall performance of the Egyptian bottled water sector.	1- Online references, periodicals and specialised journals
April 2009	An overview of the bottled water company through briefly outlining what the company does, how it developed historically, the company's current situation and the problems it is experiencing.	1- Documentation 2- Archival records 3- Direct observation (casual) 4- Interview (unstructured) 5- Informants 6- Online references
May 2009	Analysis of the characteristics, the structure and the strategy of the bottled water company's existing supply chain.	1- Documentation 2- Archival records 3- Direct observation (casual) 4- Interview (unstructured) 5- Informants 6- Online references, periodicals and specialised journals
Case study design		
Time	**Targeted output**	**Data collection method/ model /technique**
June – July 2009	Mapping the main processes and sub processes of the bottled water company's supply chain based on the SCOR model standard description of SC processes.	1- Archival records 2- Direct observation (formal, casual) 3- Interview (semi-structured/focus group) 4- SCOR Model version 9 5- Informants
August 2009	Identification of the corresponding performance measures for the mapped processes based on the SCOR model standard performance metrics.	1- Documentation 2- Archival records 3- SCOR Model version 9 4- Informants
September – October 2009	Determination of the relative importance weights of the bottled water company's supply chain performance measurement attributes and sub-attributes.	1- Documentation. 2- Archival records. 3- Interview (formal survey) 4- Informants.

November – December 2009	Establishment of the performance rating scale for each of the supply chain performance measurement attributes and sub-attributes.	1-Documentation 2- Archival records 3- Focus group 4- Informants
Case study implementation and analysis		
Time	**Targeted output**	**Data collection method/ model /technique**
January – December 2010	Analysis of the current supply chain performance of the bottled water company's supply chain.	1- Documentation 2- Archival records 3- Informants
January 2010/ January 2011	Analysis of the current financial performance of the bottled water company.	1- Documentation 2- Archival records
January 2011	Determination of the priorities of the bottled water company's financial performance objectives.	1- Documentation 2- Archival records 3- Interview (formal survey) 4- Informants 5- Financial performance metrics

3- Case Study Questions

Introductory phase

1. What are the Egyptian bottled water industry's features and characteristics?
2. What is the overall performance of the Egyptian bottled water sector?
3. What does the bottled water company do, how it developed historically, what is the company's current situation and what problems it is experiencing?
4. What is the characteristics, the structure and the strategy of the bottled water company's existing supply chain?

Case study design

1. What are the main processes and sub processes of the bottled water company's supply chain?
2. What are the corresponding performance measures for the main processes and sub processes of the bottled water company's supply chain?
3. What are the relative importance weights of the bottled water company's supply chain performance measurement attributes and sub-attributes?
4. What is the performance rating scale for each of the supply chain performance measurement attributes and sub-attributes?

Case study implementation and analysis

1. What is the current supply chain performance index of the bottled water company's supply chain?
2. What is the relative importance weight of each of the bottled water company's financial performance measurement attributes?
3. What is the current SCFLI of The bottled water company?
4. What is the impact of the bottled water company's supply chain operations' performance on its overall financial performance?

4- Guide for the case study report

Introduction

- Introduction to the research topic
- Research aim and objectives
- Research methodology
- Research originality
- Structure of the dissertation

Literature review

Part 1: Performance measurement

- Performance measurement general issues
- Supply chain performance measurement
- Previous studies available on the link between supply chain performance and financial performance

Part 2: Supply chain performance measurement

- Designing and implementing a performance measurement system in a SC context
- The SCOR Model
- The FAHP method
- Combining the SCOR model and the FAHP method

Part 3: Financial performance measurement

- Du Pont ratio analysis
- DS/AHP model

Part 4: Case study research design and methods

Research approach

Part 1: Incorporating FAHP in SCOR model for measuring SC operations' performance

Part 2: Linking supply chain operations' performance to a company's strategic financial objectives

Research methodology

- Case design
- Preparation for data collection
- Data collection (introductory phase, establishing the SCOR FAHP technique and implementation phase)
- Data analysis
- Case study report

Findings from collected and analysed data

- Case study
- The analytic generalisation of findings

Conclusion and recommendations for future work

- Realisation of research aim and objectives
- Research findings and contribution to knowledge
- Research limitations
- Recommendations for future work

APPENDIX 2- Introductory training seminar for the case study's participants

An introductory training seminar for the case study participants from the bottled water company

Date: Friday, 13 November 2009

Duration: 3 hours

Start time: 2:30 pm

Location: The bottled water company Plant, Siwa Oasis, Egypt

Speakers:

- Business planning manager
- The research investigator

Attendees:

- Plant manager
- Commercial manager
- Quality assurance manager
- Engineering division manager
- Production manager
- Warehousing manager
- Follow up manager
- Attendee from the quality assurance department
- Two attendees from the engineering division
- Attendee from the production division
- Two attendees from the warehousing division

Objective:

An introductory seminar will be held to have all participants understand the basic concepts, terminologies, and issues relevant to the research.

Seminar agenda:

Time	Topics	Speaker
2:30-2:45	Introduction	Business planning manager
2:45-3:30	Purpose of the case study and research questions	The research investigator
3:30-4:15	Case study protocol	The research investigator
4:15-4:30	Break	
4:30-5:00	Schedule for conducting the case study (define deadlines)	The research investigator
5:00-5:30	Open discussion	

APPENDIX 3- Interviews protocols

Appendix 3.1- Unstructured interview protocol

Appendix 3.2- Semi structured interview protocol

Appendix 3.3- Structured interview (1) protocol

Appendix 3.4- Structured interview (2) protocol

Appendix 3.5- Structured interview (3) protocol

Appendix 3.1- Unstructured interview protocol

Title

"Get an overview of the bottled water company and understand its supply chain"

Purpose

- Get an overview of the bottled water company through briefly outlining what the company does, how it developed historically, what is the company's current situation and what problems it is experiencing.
- Understand the bottled water company's supply chain through identifying the main members in the supply chain, analysing the structural dimensions of the supply chain, determining supply chain structural classification, mapping the geographical dispersion of the supply chain and identifying supply chain strategy

Participants

The interview will be conducted with the research informants, managing director and plant manager:

- Business planning manager
- Commercial manager
- Managing director
- Plant manager

Procedures

Unstructured interviews will be conducted with open ended questions.

Introduction

Thank you for coming. Our interview today aims at getting an overview of your company and to understand your company's supply chain as a start to our research. This is a "no holds barred" discussion. We want to know what you are seeing, even if it looks bad. That is the only way we are going to improve your company. Of course, we also want to know where things are going well, and where they are not going well. We really need to hear that message. The discussion will take approximately 60 minutes and be sure that anything you say here will be held in strict confidence.

Questions

The following questions will be asked, in sequence:

- What the company does?
- How was it developed historically?
- What is the company's current situation?
- What are the problems it is experiencing?
- What are the main members of its supply chain?
- What is its supply chain strategy?

Conclusion

What I have heard you saying was………., did I summarise your words correctly? Is there anything you would like to add or amend?

Thank you for your attendance and participation.

Appendix 3.2- Semi structured interview protocol

Title

“Identify the main processes and sub processes of the bottled water company’s supply chain**”**

Purpose

Draw a flowchart to represent the main processes and sub processes of the bottled water company’s supply chain through describing the sequence of tasks and decision points as they actually happen. For each department and division those who do the work, the suppliers to the processes, the customers of the processes and the supervisors and the managers of the processes will be identified.

Participants

The interview will be conducted with the managers of main departments and divisions in the company:

- Business planning manager
- Commercial manager
- Quality assurance manager
- Engineering division manager
- Production manager
- Warehousing manager

Procedures

Semi-structured interview will be conducted with the managers of main departments and divisions in the company.

Introduction

Thank you for coming. Our interview today is mainly concerned with drawing together a flow chart for your department/division processes and identifying who does the work, the suppliers to your processes, the customers of your processes and the supervisors and managers of your processes. The discussion will take approximately 45 minutes. Anything you say here will be held in strict confidence.

Questions

The following questions will be asked at various steps in the process:

- What are the inputs to the processes under consideration?
- Where does your work come from?
- What do you do with it?
- Where do you send your output?
- What form does that output take?

Conclusion

What I have heard you saying ………., did I summarise your words correctly? Is there anything you would like to add or amend?

Thank you for your attendance and participation.

Appendix 3.3- Structured interview (1) protocol

Title

“Prioritising the relative importance weights of the bottled water company’s supply chain performance measurement attributes and sub-attributes**”**

Purpose

To determine the relative weights of the bottled water company’s supply chain performance measurement attributes and sub-attributes at different levels, from implementation levels till configuration level, using a fuzzy pair wise comparison survey.

Participants

The interview will be conducted with:

- Business planning manager
- Commercial manager
- Quality assurance manager
- Engineering division manager

Procedures

Structured interview will be conducted with assembled experts group that includes four experts (business planning manager, commercial manager, quality assurance manager and engineering manager). A fuzzy pair wise questionnaire will be used to facilitate comparison of supply chain performance measurement attributes at different levels till the configuration level.

Introduction

Thank you for coming. Our interview today focuses on determining the relative weight of each of the bottled water company’s supply chain performance measurement attributes and sub-attributes. The survey will take approximately 60 minutes. Anything you say here will be held in strict confidence.

Questions

The following questionnaire form will be used to facilitate comparison of supply chain performance measurement attributes at different levels till configuration level. For this survey, 52 metrics include 153 pairs of comparison are established.

The relative importance of two elements is rated using a scale with the values 1, 3, 5, 7 and 9, where 1 denotes equally important, 3 slightly more important, 5 strongly more important, 7 demonstrably more important and 9 absolutely more important.

For any metrics at any level, if the value of consistency ratio (CR) is smaller or equal to 10%, the inconsistency is acceptable. If the CR is greater than 10%, the pair-wise comparison processes are repeated until the consistency ratio is less than 0.1.

With respect to (……..)	Importance or preference of one main (sub) attribute over another									
Attribute	Absolutely more important **(9)**	Demonstrably more important **(7)**	Strongly more important **(5)**	Slightly more important **(3)**	Equally important **(1)**	Slightly more important **(3)**	Strongly more important **(5)**	Demonstrably more important **(7)**	Absolutely more important **(9)**	**Attribute**
C1										C2
…..										.....
Cn-1										Cn

"Questionnaire form to facilitate comparison of SC performance measurement attributes"

Conclusion

Is there anything you would like to add or amend?

Thank you for your attendance and participation.

Appendix 3.4- Structured interview (2) protocol

Title

"Determining the priorities of the bottled water company's financial performance factors**"**

Purpose

To assign the priorities of the financial performance factors – with respect to Du Pont analysis results– using a pair-wise questionnaire form**.**

Participants

The interview will be conducted with a group of decision makers at the strategic level comprising:

- Managing director
- Business planning manager
- Supply chain manager
- Financial manager

Procedures

Du Pont analysis results for the year ended December 31st 2010 will be illustrated and discussed with the assembled decision makers group. Then, the structured interview will be conducted. The interviewees will be asked to assign the relative importance weights of financial performance factors (profitability (P) and efficiency (E)) for the new accounting period (2011) with respect to Du Pont analysis results using a pair wise questionnaire form.

Introduction

Thank you for coming. Our interview today aims at determining the relative importance weight of the financial performance factors profitability (P) and efficiency (E)) with respect to Du Pont analysis results. The survey will take approximately 30 minutes. Anything you say here will be held in strict confidence.

Questions

The following pair wise questionnaire form will be used to determine the priorities of financial performance factors, based on a scale with the values 1, 3, 5, 7, and 9, where 1 denotes equally important, 3 slightly more important, 5 strongly more important, 7 demonstrably more important and 9 absolutely more important.

With respect to (financial performance)	Importance or preference of one factor over another									
Attribute	Absolutely more important (9)	Demonstrably more important (7)	Strongly more important (5)	Slightly more important (3)	Equally important (1)	Slightly more important (3)	Strongly more important (5)	Demonstrably more important (7)	Absolutely more important (9)	Attribute
Profitability (P)										Efficiency (E)

Questionnaire form to facilitate comparison of the importance of financial performance factors

Conclusion

Is there anything you would like to add or amend?

Thank you for your attendance and participation.

Appendix 3.5- Structured interview (3) protocol

Title

"Determine the relative importance weights of the bottled water company's five main supply chain performance measures with respect to the financial performance priorities**"**

Purpose

DS/AHP approach will be conducted to determine the relative importance weights of the main supply chain performance measures (RL, RS, AG, CO, AM) with respect to the priorities of financial performance factors.

Participants

The interview will be conducted with the group of decision makers - which was assembled at the second structured interview - in order to determine the priorities of financial performance factors. The group includes:

- Managing director
- Business planning manager
- Supply chain manager
- Financial manager

Procedures

The priorities of financial performance factors (profitability (P) and efficiency (E)) for the new accounting period (2011) with respect to Du Pont analysis results will be illustrated and discussed with the assembled decision makers group. Then, structured interview will be conducted. The interviewees will be asked to rank the five main supply chain performance measures priorities with respect to financial performance priorities - using a scale (adapted from that in the AHP method) as a basis for discriminating levels of preference.

Introduction

Thank you for coming. Our interview today focuses on determining the relative importance weight of the five main supply chain performance measures with respect to financial performance priorities. The survey will take approximately 45 minutes. Anything you say here will be held in strict confidence.

Questions

The following questionnaire forms will be used to determine the relative importance weights of the five main supply chain performance measures –with regard to each financial performance factor - using the following scale (adapted from that in the AHP method) with the values 3, 5, 7 and 9 as a basis for discriminating levels of preference, where 3 indicates slightly more important, 5 strongly more important, 7 demonstrably more important and 9 absolutely more important. It is important to note that the method does not use the equally preferred rating of 1 (as in the AHP method); this being a consequence of evaluating groups of D.A.'s *vis a vis* the frame of discernment θ (all D.A.'s). In addition, since not pair-wise comparisons of D.A.'s but relating groups of D.A.'s to θ are performed, there are no consistency problems within a criterion, as long as no two proper subsets of θ considered in a criteria have a D.A.

With respect to (Profitability)	Importance or preference of one factor over the frame of discernment θ (all D.A.'s)	
Attribute	Absolutely more important (9) Demonstrably more important (7) Strongly more important (5) Slightly more important (3) Slightly more important (3) Strongly more important (5) Demonstrably more important (7) Absolutely more important (9)	Attribute
RL		θ
RS		θ
CO		θ
AG		θ

Questionnaire form to facilitate comparison of the importance of SC main performance measures with respect to profitability factor

With respect to (Efficiency)	Importance or preference of one factor over the frame of discernment θ (all D.A.'s)									
Attribute	Absolutely more important (9)	Demonstrably more important (7)	Strongly more important (5)	Slightly more important (3)		Slightly more important (3)	Strongly more important (5)	Demonstrably more important (7)	Absolutely more important (9)	Attribute
RL										θ
RS										θ
AM										θ

Questionnaire form to facilitate comparison of the importance of SC main performance measures with respect to efficiency factor

Conclusion

Is there anything you would like to add or amend?

Thank you for your attendance and participation.

APPENDIX 4- Focus groups protocols

Appendix 4.1- Focus group (1) protocol

Appendix 4.2- Focus group (2) protocol

Appendix 4.1- Focus group (1) protocol

Title

“Review the flowchart of the main processes and sub processes of the bottled water company’s supply chain**”**

Purpose

The initial flowchart that was drawn to represent the processes will be reviewed by the focus group to ensure that the processes were correctly identified and linked.

Participants

A group will be assembled comprising representatives from all departments involved in the research, who have good knowledge and understanding of the processes under examination. However, the departments and divisions managers cannot be included in the focus groups since their participation would skew and reduce the free interaction of the focus group discussions.

- Assistant commercial manager
- Attendee from the quality assurance department
- Two attendees from the engineering division
- Attendee from the production division
- Two attendees from the warehousing division

Focus group procedures

Focus group will be conducted in a semi-structured interview format. The interview has a short list of open-ended questions to ask.

Introduction

Thank you for coming. We have brought you together so that we can review and evaluate the initial flowchart that was drawn to represent the processes of your company’s supply chain in order to ensure that the processes were correctly identified and linked. This is a ``no holds barred" discussion. We want to know what you are seeing. The discussion will take approximately 90 minutes. Anything you say here will be held in strict confidence; we will not be telling people outside this room who said what.

Questions

The following questions will be asked and the group discussed each question, in sequence:

- What do you think about this flowchart?
- Does this flow chart clearly identify the main processes and the sub processes in your company?
- Does this flow chart correctly reflect the links between the main processes and the sub processes in your company?
- Do you think that there are any changes or modifications required to this flowchart?

Conclusion

What I have heard you saying ………., did I summarise your thoughts correctly? Is there anything you would like to add or amend?

Thank you for your attendance and participation.

Appendix 4.2- Focus group (2) protocol

Title

“Establish a performance rating scale for the bottled water company’s SC performance measurement attributes**”**

Purpose

Since there is no historical data available in the company about the newly developed measures, a focus group will be assembled to establish a five point performance rating scale (very poor, poor, good, very good and excellent) for these newly developed measures.

In addition, in order to identify the excellent performance in the scale for the existing measures, the focus group will be asked to determine the targeted percentage increase in the performance above the maximum historical performance.

Participants

A group of experts has been assembled comprising:

- Business planning manager
- Commercial manager
- Quality assurance manager
- Engineering division manager

Focus group procedures

Focus group will be conducted in a semi structured interview format.

Introduction

Thank you for coming. We've brought you together so that we can establish a performance rating scale for SC performance measures. This is a "no holds barred" discussion. We want to know what you are seeing. The discussion will take approximately 90 minutes. Anything you say here will be held in strict confidence; we will not be telling people outside this room who said what.

Questions

1- The following questionnaire form will be used to determine the minimum and the maximum expected performance for each of the newly developed measures taking into consideration the company's business environment, current situation, strategies and goals.

Attribute code	Attribute name	Maximum expected performance	Minimum expected performance
A.2- 1			
………			
A.5-n			

2- In your opinion, for the existing measures, what is the percentage increase above the maximum historical performance that represents excellent performance taking into consideration the company's business environment, current situation, strategies and goals? Why?

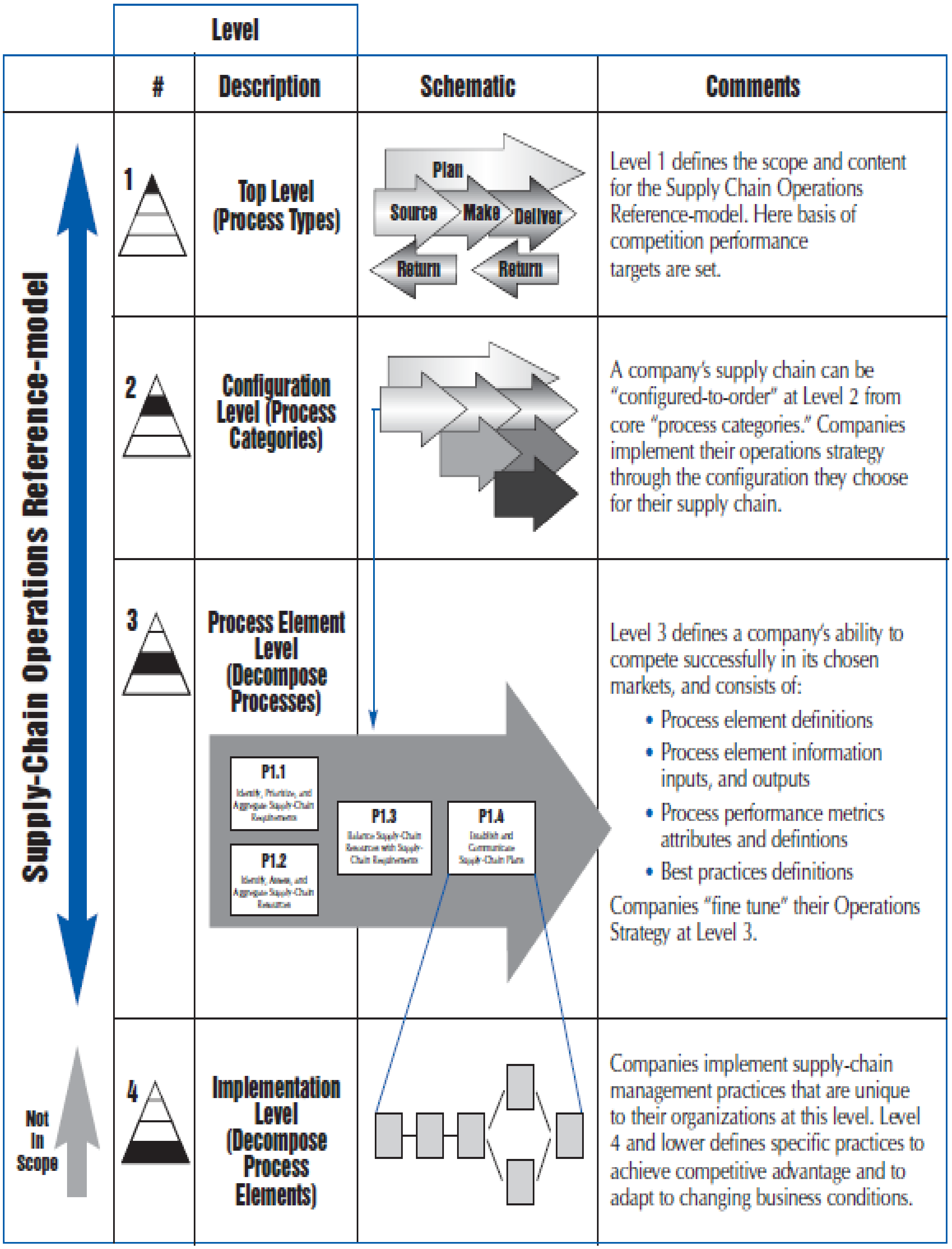
Conclusion

What I have heard you saying ………., did I summarise your thoughts correctly? Is there anything you would like to add or amend?

Thank you for your attendance and participation.

APPENDIX 5- The bottled water company's SC processes map

The general structure of applying the SCOR model



(Source: SCOR Model - Version 9, Supply Chain Council, 2008)

Figure A5.1: The SCOR model's general structure

Example:

Figure A5.2 presents an example of how SCOR model can be employed to achieve intra-organisational cross functional business processes integration. The example assumes that the focal company manufactures bottled water and has a "build to stock" strategy. Tier one supplier represents the supplier of the plastic bottles which is considered the main direct material item.

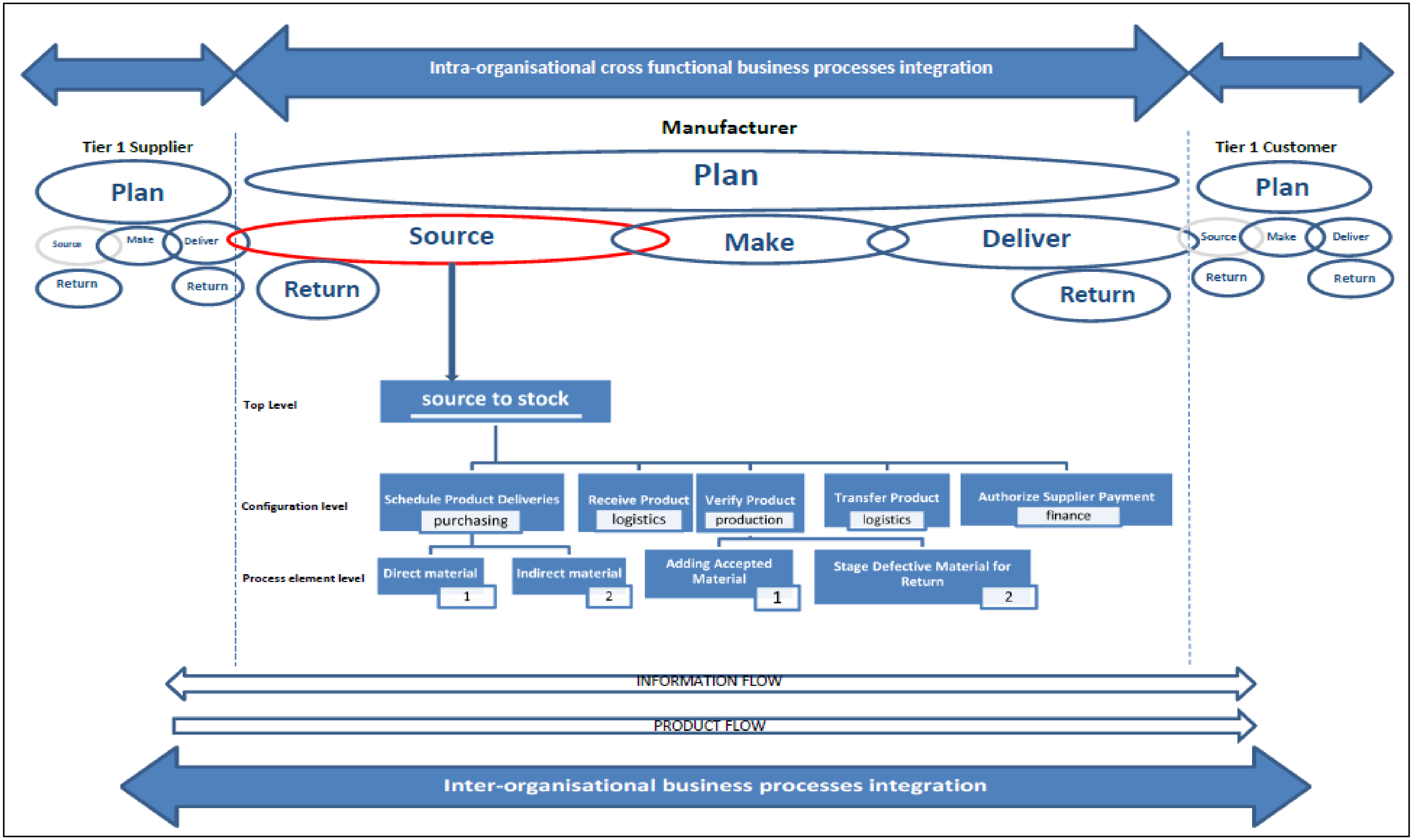
The figure illustrates the SCOR "sourcing" process in the focal company at different levels of the SCOR hierarchy (top level, configuration level and process element level). "Source to stock" process at top level presents the overall source process as an aggregation of the source sub processes (procurement, delivery, receipt and transfer of plastic bottles) at the lowest levels in the hierarchy.

At the configuration level, source to stock process is classified into five sub standardised processes performed across different business functions. As shown in figure A5.2, the purchasing department is responsible for scheduling and managing the execution of the individual deliveries of plastic bottles. Then these individual deliveries are received by the logistics department. Once the deliveries are received, the production department takes the necessity actions to determine product conformance to requirements and criteria. Accordingly, the logistics department transfers accepted plastic bottles to the appropriate stocking location within the company. Finally, the finance department authorises payments and pays plastic bottles supplier.

At process element level, some of the configuration level sub processes are divided into more detailed processes to be implemented by specific divisions. Schedule product deliveries process is classified into two sub processes, whereas a specific division is responsible for direct material product deliveries and another division carries out indirect material product deliveries. Also the verification process at the configuration level is implemented through two sub processes carried out at the process element level. As illustrated in figure A5.2, the verification process of the received deliveries ends with two actions: adding accepted materials which are conformant to requirements and criteria and stage defective material for return.

The example demonstrates the implementation of cross functional business process integration within a company based on the SCOR model standard description of SC processes at different levels of processes details. This example will be extended in Appendix 6 to illustrate how the performance of these processes can be measured based on the SCOR model standard performance metrics.

The bottled water company's supply chain processes mapping at the process element level and the implementation levels is presented in table A5.1.



(Developed from: Lambert and Cooper, 2000; and SCOR Model - Version 9, Supply Chain Council, 2008)

Figure A5.2: An example of intra-organisational cross functional business processes integration based on SCOR model

Table A5.1: The bottled water company's supply chain processes mapping at the process-element level and the implementation levels

Process -Element level					
process code	process name	definition	process inputs	process outputs	responsible department
P1-1	Identify, Prioritize, and Aggregate Supply Chain Requirements	The process of identifying, aggregating, and prioritizing, all sources of demand for the integrated supply chain of a product or service at the appropriate level, horizon and interval.	customer requirements including sales forecasts and actual orders	supply chain requirements to P1-3/P2-1	The Distributor Company
P1-2	Identify, Assess, and Aggregate Supply Chain Resources	The process of identifying, prioritizing, and aggregating, as a whole with constituent parts, all sources of supply that are required and add value in the supply chain of a product or service at the appropriate level, horizon and interval.	Capital plan/ Source plan from P2-4	supply chain resources to P1-3	Follow-up department /Commercial department /Financial department
P1-3	Balance Supply Chain Resources with Supply Chain Requirements	The process of identifying and measuring the gaps and imbalances between demand and resources in order to determine how to best resolve the variances through marketing, pricing, packaging, warehousing, outsource plans or some other action that will optimize service, flexibility, costs, assets, (or other supply chain inconsistencies) in an iterative and collaborative environment. The process of developing a time-phased course of action that commits supply chain resources to meet supply-chain requirements.	P1-1/ P1-2	Work flow to P1-4	Managing director with assistance of planning department
P1-4	Establish Supply Chain Plans	The establishment and communication of courses of action over the appropriate time-defined (long-term, annual, monthly, weekly) planning horizon and interval, representing a projected appropriation of supply-chain resources to meet supply-chain requirements.	P1-3/P1-4-1/ P1-4-2/P1-4-3	Work flow to P2-1,P3-1,P4-1, P5-1	Managing director

P2-1	Identify, Prioritize, and Aggregate Product Requirements	The process of identifying, prioritizing, and considering, as a whole with constituent parts, all sources of demand for a product or service in the supply chain.	P1-1/P1-4/ P3-4/P4-4/ P5-4/Bill of materials	Product requirements to P2-3	Commercial department for DM /Follow-up department for INDM/ planning department for machines with assistance of Warehousing department
P2-2	Identify, Assess, And Aggregate Product Resources	The process of identifying, evaluating, and considering, as a whole with constituent parts, all material and other resources used to add value in the supply chain for a product or services.	Inventory availability from S1-4/Product on order from S1-1,Product inventory target level	Product sources to P2-3	Commercial department for DM /Follow-up department for INDM/ planning department for machines with assistance of Warehousing department
P2-3	Balance Product Resources with Product Requirements	The process of developing a time-phased course of action that commits resources to meet requirements.	P2-1/P2-2	Work flow to P2-4	Commercial department for DM /Follow-up department for INDM/ planning department for machines with assistance of Warehousing department
P2-4	Establish Sourcing Plans	The establishment of courses of action over specified time periods that represent a projected appropriation of supply resources to meet sourcing plan requirements.	P2-3	P1-2, S1-1, P3-2, P4-2, P5-1, P5-2, D1-3	Commercial department for DM /Follow-up department for INDM/ planning department for machines with assistance of Warehousing department
P3-1	Identify, Prioritize, and Aggregate Production Requirements	The process of identifying, prioritizing, and considering as a whole with constituent parts, all sources of demand in the creation of a product or service.	P1-1/P1-4/ P4-4/P5-4/Bill of materials	Production requirements to P3-3	Commercial department/ Production department
P3-2	Identify, Assess, and Aggregate Production Resources	The process of identifying, evaluating, and considering, as a whole with constituent parts, all things that add value in the creation of a product or performance of a service.	P2-4/Inventory availability from M1-2 /Equipment and facilities plan	Production resources to P3-3	Commercial department/ Production department

P3-3	Balance Production Resources with Production Requirements	The process of developing a time-phased course of action that commits creation and operation resources to meet creation and operation requirements.	P3-1/P3-2	Work flow to P3-4	Commercial department/ Production department
P3-4	Establish Production Plans	The establishment of courses of action over specified time periods that represent a projected appropriation of supply resources to meet production and operating plan requirements.	P3-3	P1-2/P2-1/P4-2/P5-1/ P5-2/M1-1/ M1-5/D1-3 /Manage equipment and facilities	Commercial department/ Production department
P4-1	Identify, Prioritize, and Aggregate Delivery Requirements	The process of identifying, prioritizing, and considering, as a whole with constituent parts, all sources of demand in the delivery of a product or service.	P1-4/P5-4/Lead time/ Transportation plan/EOQ	Delivery requirements to P4-3	Follow-up department /Production department/The Distributor Company
P4-2	Identify, Assess, and Aggregate Delivery Resources and Capabilities	The process of identifying, evaluating, and considering, as a whole with constituent parts, all things that add value in the delivery of a product or service.	P2-4/P3-4/D1-3	Delivery resources and capabilities to P4-3	Follow-up department /Production department/The Distributor Company
P4-3	Balance Delivery Resources and Capabilities with Delivery Requirements	The process of developing a time-phased course of action that commits delivery resources to meet delivery requirements.	P4-1/P4-2	Work flow to P4-4	Follow-up department /Production department/The Distributor Company
P4-4	Establish Delivery Plans	The establishment of courses of action over specified time periods that represent a projected appropriation of delivery resources to meet delivery requirements.	P4-3	P1-2/P2-1/ P3-1/P5-1/ P5-2/M1-5/D1-3	Follow-up department /Production department/The Distributor Company
P5-1	Assess, and Aggregate Return Requirements	The process of identifying, evaluating, and considering, as a whole with constituent parts, all sources of demand for the return of a product.	Business rules for return process/Historical return rate from SR1-3, DR1-1/ P1-4 /P2-4/ P3-4/P4-4	Return requirements to P5-3	Follow-up department/Quality department

P5-2	Identify, Assess, and Aggregate Return Resources	The process of identifying, evaluating, and consideration for all resources that add value to, execute, or constrain the processes for the return of a product.	Business rules for return process/ DR1-3 /DR1-4/ P2-4 /P3-4/P4-4	Return resources and capabilities to P5-3	Follow-up department/Quality department
P5-3	Balance Return Resources with Return Requirements	The process of developing courses of action that make feasible the commitment the appropriate return resources and or assets to satisfy return requirements.	P5-1/P5-2	Work flow to P5-4	Follow-up department/Quality department
P5-4	Establish and Communicate Return Plans	The establishment and communication of courses of action over specified time periods that represent a projected appropriation of required return resources and or assets to meet return process requirements.	P5-3	P2-1/P3-1/P4-1/ DR1-1/SR1-2	Follow-up department/Quality department
S1-1	Schedule Product Deliveries	Scheduling and managing the execution of the individual deliveries of product against an existing contract or purchase order. The requirements for product releases are determined based on the detailed sourcing plan or other types of product pull signals.	Production schedule from M1-1/M1-2/ D1-3/P2-4 /Supplier performance/ Logistics selection	Work flow to S1-2/ P2-2/M1-1/ Supply Order Document	Commercial department for DM with assistance of Warehousing department/ Follow-up department for INDM with assistance of Warehousing department and engineering department
S1-2	Receive Product	The process and associated activities of receiving product to contract requirements.	Product from source/S1-1/ DR1-4/Supply Order Document	Work flow to S1-3	Warehousing department/ The keeper of Material warehouse (for DM)/ The keeper of Spare parts warehouse (for INDM)
S1-3	Verify Product	The process and actions required determining product conformance to requirements and criteria.	S1-2	Work flow to S1-4/ SR1-1/Supplier performance/ Verification and Inspection report/Adding material document/ Returns material document	Warehousing department and Quality department(for DM inspection)/ Warehousing department and engineering department (For INDM inspection)

S1-4	Transfer Product	The transfer of accepted product to the appropriate stocking location within the supply chain. This includes all of the activities associated with repackaging, staging, transferring and stocking product. For service this is the transfer or application of service to the final customer or end user.	S1-3/Inventory location/ D1-3/Adding material document from S1-3	Work flow to S1-4/ SR1-1/ Supplier performance	Warehousing department/ The keeper of Material warehouse (for DM)/ The keeper of Spare parts warehouse (for INDM)
S1-5	Authorize Supplier Payment	The process of authorizing payments and paying suppliers for product or services. This process includes invoice collection, invoice matching and the issuance of checks.	S1-3/ S1-4/Payment terms/ SR1-5	……………………………	Financial department (with the assistance of Commercial department for DM and Follow-up department for INDM)
M1-1	Schedule Production Activities	Given plans for the production of specific parts, products, or formulations in specified quantities and planned availability of required sourced products, the scheduling of the operations to be performed in accordance with these plans. Scheduling includes sequencing, and, depending on the factory layout, any standards for setup and run. In general, intermediate production activities are coordinated prior to the scheduling of the operations to be performed in producing a finished product.	Equipment and facilities schedule/S1-1/P3-4	Work flow to M1-2 / S1-1/D1-3	Commercial department and Production department with assistance of Warehousing department
M1-2	Issue Material	The selection and physical movement of sourced/in-process product (e.g., raw materials, fabricated components, subassemblies, required ingredients or intermediate formulations) from a stocking location (e.g., stockroom, a location on the production floor, a supplier) to a specific point of use location. Issuing product includes the corresponding system transaction. The Bill of Materials/routing information or recipe/production instructions will determine the products to be issued to support the production operation(s).	M1-1/Inventory availability from S1-4/Issuing material request document	Work flow to M1-3 /S1-1/ D1-3/P3-2/ Feed back to M1-1 /Issuing material document	The keeper of Direct Material warehouse

M1-3	Produce and Test	The series of activities performed upon sourced/in-process product to convert it from the raw or semi-finished state to a state of completion and greater value. The processes associated with the validation of product performance to ensure conformance to defined specifications and requirements.	M1-2/ Production standards	Work flow to M1-4/Feed back to M1-1	The production department and The Quality department
M1-4	Package	The series of activities that containerize completed products for storage or sale to end-users. Within certain industries, packaging may include cleaning or sterilization.	M1-3	Work flow to M1-5 /Feed back to M1-1	The production department and The Quality department
M1-5	Stage Product	The movement of packaged products into a temporary holding location to await movement to a finished goods location. Products that are made to order may remain in the holding location to await shipment per the associated customer order. The movement to finished goods is part of the Deliver process.	M1-4/P3-4/ P4-4/Adding finished product request document	Work flow to M1-6 /Feed back to M1-1	Warehousing department/ The keeper of finished product warehouse
M1-6	Release Product to Deliver	Activities associated with post-production documentation, testing, or certification required prior to delivery of finished product to customer. Examples include assembly of batch records for regulatory agencies, laboratory tests for potency or purity, creating certificate of analysis, and signoff by the quality organization.	M1-5/Delivery for loading document	D1-5/Feed back to M1-1	Warehousing department/ The keeper of finished product warehouse
D1-1	Process Inquiry & Quote	Receive and respond to general customer inquiries and requests for quotes.	Customer inquiry from The Distributor Company/ supply order from sales	Customer quote to D1-2	The Distributor Company

D1-2	Receive, Enter & Validate Order	Receive orders from the customer and enter them into a company's order processing system. Orders can be received through phone, fax, or electronic media. "Technically" examine orders to ensure an orderable configuration and provide accurate price. Check the customer's credit. Optionally accept payment.	D1-1/Deliver contract terms	Validate order to D1-3/ Manage transportation	Follow-up department
D1-3	Reserve Inventory & Determine Delivery Date	Inventory and/or planned capacity (both on hand and scheduled) is identified and reserved for specific orders and a delivery date is committed and scheduled.	P2-4/P3-4/ P4-4/M1-1/ M1-2/S1-4/D1-2	D1-4/P4-1/P4-2/S1-1/ Replishment signal from S1-4	Follow-up department with assistance of Warehousing department
D1-4	Receive Product from Source or Make	The activities such as receiving product, verifying, recording product receipt, determining put-away location, putting away and recording location that a company performs at its own warehouses. May include quality inspection.	M1-6	Work flow to D1-5	Warehousing department /Quality department
D1-5	Pack Product	The activities such as sorting / combining the products, packing / kitting the products, paste labels, barcodes etc. and delivering the products to the shipping area for loading.	D1-4	Work flow to D1-6	Warehousing department /Quality department
D1-6	Load Vehicle & Generate Shipping Documentation	The series of tasks including placing/loading product onto modes of transportation and generating the documentation necessary to meet internal, customer, carrier and government needs.	Shipping documentation	Delivered end item to customer/ Shipping documents to customer and to carrier	Warehousing department /Quality department
D1-7	Ship Product	The process of shipping the product to the customer site.	Work flow from D1-6	Work flow to D1-8	The transportation company
D1-8	Receive & Verify Product by Customer	The process of receiving the shipment by the customer site (either at customer site or at shipping area in case of self-collection) and verifying that the order was shipped complete and that the product meets delivery terms.	Work flow from D1-7	Work flow to D1-9/ Signature of customer on shipping documents	The transportation company

D1-9	Invoice	A signal is sent to the financial organization that the order has been shipped and that the billing process should begin and payment be received or be closed out if payment has already been received. Payment is received from the customer within the payment terms of the invoice.	Work flow from D1-8	Payment to the company	Financial department (with the assistance of Commercial department)
SR1-1	Identify Defective Product Condition	The process where the customer utilizes planned policies, business rules and product operating conditions inspection as criteria to identify and confirm that material is excess to requirements defective.	Business rules for return process/supply order from S1-1-1-7 or from S1-1-2-4 /S1-3/ S1-1-3	Returned defective product to SR1-2	Warehousing department and Quality department(for DM inspection)/ Warehousing department and engineering department (For INDM inspection)
SR1-2	Disposition Defective Product	The process of the customer determining whether to return the defective item and the appropriate source contact for a return authorization.	P5-4/SR1-1	Work flow to SR1-3	Commercial department for DM and Follow-up department for INDM)
SR1-3	Request Defective Return Authorization	The process of a customer requesting and obtaining authorization, from last known holder or designated return center, for the return of defective product. Additionally, the customer and last known holder or designated return center would discuss enabling conditions such as return replacement or credit, packaging, handling, transportation and import / export requirements to facilitate the efficient return of the defective product.	SR1-2	Work flow to SR1-4/P5-1	Commercial department for DM and Follow-up department for INDM)
SR1-4	Schedule Defective Product Shipment	The process where the customer develops the schedule for a carrier to pick-up for delivery of the defective product. Activities include selecting the carrier and rates, preparing the item for transfer, preparing scheduling documentation and managing overall scheduling administration.	SR1-3	Work flow to SR1-5	Commercial department for DM and Follow-up department for INDM)

SR1-5	Return Defective Product	The process where the customer packages, and handles the defective product in preparation for shipping in accord with pre-determined conditions. The product is then provided by the customer to the carrier who physically transports the product and its associated documentation to the last known holder or designated return center.	SR1-4	Shipment documents/S1-5	Warehousing department under the supervision of Production department for DM/Follow-up department for INDM
DR1-1	Authorize Defective Product Return	The process where the last known holder or designated return center receives a defective product return authorization request from a customer, determines if the item can be accepted and communicates decision to the customer. Accepting the request would include negotiating the conditions of the return with the customer, including authorizing return replacement or credit. Rejecting the request would include providing a reason for the rejection to the customer.	Business rules for return process/ P5-4/Customer Complaint/ Finished Product Quality Analysis Reports	Work flow to DR1-2/P5-1/ Defectives Verification and Inspection Report/ Defective Product Returns Document	The Distributor Company/ Follow-up department/Quality department
DR1-2	Schedule Defective Return Receipt	The process where the last known holder or designated return center evaluates the defective product handling requirements including negotiated conditions and develops a schedule that tells the Customer when to ship the product. The scheduling activity would also inform Receiving when to expect the shipment and where to send the product, for disposition, upon receipt.	DR1-1/ Defectives Verification and Inspection Report/ Defective Product Returns Document	Work flow to DR1-3	The Distributor Company/Follow-up department
DR1-3	Receive Defective Product	The process where the last known holder or designated return center receives and verifies the returned defective product against the return authorization and other documentation and prepares the item for transfer.	DR1-2/Return transportation guidelines	Work flow to DR1-4/P5-2/ Receipt discrepancy notification to enable return	The Distributor Company

DR1-4	Transfer Defective Product	The process where the last known holder or designated return center transfers the defective product to the appropriate process to implement the disposition decision.	DR1-3	P5-2/S1-2/ Returns and damages sales committee	Warehousing department
Implementation level one					
process code	process name	Explanation	process inputs	process outputs	responsible department
P1-4-1	Setting Supply Chain Objectives		P1-3	Work flow to P1-4-2	Managing director
P1-4-2	Plan of Course of Action	Plan of course of action over level horizon and intervals to accomplish setting objectives	P1-4-1/P1-3	Work flow to P1-4	Managing director
P1-4-3	Establish Expenses Budget		P1-4-2/P1-3	Work flow to P1-4	Vice _chairman / Managing director/ planning department/ Financial department
S1-1-1	Schedule Product Deliveries for Direct Material	Scheduling and managing the execution of the individual deliveries of direct material against an existing contract or purchase order. The requirements for product releases are determined based on the detailed sourcing plan or other types of product pull signals.	Production schedule from M1-1/M1-2/ D1-3 /P2-4/ Supplier performance/ Logistics selection	Work flow to S1-2/DM Supply Order Document	Commercial department with assistance of Warehousing department
S1-1-2	Schedule Product Deliveries for Indirect Material	Scheduling and managing the execution of the individual deliveries of indirect material(including machines, chemicals and spare parts)against an existing contract or purchase order. The requirements for product releases are determined based on the detailed sourcing plan or other types of product pull signals.	Equipment and facilities schedule/ P2-4/Supplier performance/ Logistics selection	Work flow to S1-2/INDM Supply Order Document	Follow-up department with assistance of Warehousing department and engineering department

S1-3-1	Verification and Inspection Committee	This committee is done to determine product conformance to requirements and criteria by checking 10% of the received product while the remaining quantity is checked during usage. This committee consists of the Warehousing manager and the Quality manager for DM inspection while it consists of the Warehousing manager and an engineer from Maintenance department for INDM inspection.	Material from source/ S1-2/ Supply Order document	Work flow to S1-3-2/ S1-3-3/SR1-1/S1-4/ Supplier performance/ Verification and Inspection report	Warehousing department and Quality department(for DM inspection)/ Warehousing department and engineering department (For INDM inspection)
S1-3-2	Adding Accepted Material	Based on Verification and Inspection Report and The Supply Order document, the committee prepares Adding Material document describes the material quantities and items that comply with set standards to add them to the warehouses.	Supply Order document/ Verification and Inspection report	Work flow to S1-4/ Supplier performance/ Adding material document	Warehousing department/ The keeper of Material warehouse (for DM)/ The keeper of Spare parts warehouse (for INDM)
S1-3-3	Stage Defective Material for Return	Based on Verification and Inspection Report and The Supply Order document, the committee prepares Returns Material document describes the material quantities and items that don't comply with set standards to stage them for return to the supplier.	Supply Order document/ Verification and Inspection report	Work flow toSR1-1/ Supplier performance/ Returns material document	Warehousing department/ The keeper of Material warehouse (for DM)/ The keeper of Spare parts warehouse (for INDM)
M1-3-1	Produce	The series of activities performed upon sourced/in-process product to convert it from the raw or semi-finished state to a state of completion and greater value.	M1-2/ Production and Quality standards	Work flow to M1-3-2 / M1-4/ Feed back to M1-1	The production department
M1-3-2	Test	The processes associated with the validation of product performance to ensure conformance to defined specifications and requirements.	M1-3-1 /Production and Quality standards	Work flow to M1-4 /Feed back to M1-3-1/ Finished Product Quality Analysis Reports	The Quality department
DR1-1-1	Receive Complaint		Customer Complaint	Work flow to DR1-1-2	The Distributor Company
DR1-1-2	Fill Complaint Form		DR1-1-1	Work flow to DR1-1-3	The Distributor Company

DR1-1-3	Transfer Complaint Form to the Commercial Department		DR1-1-2	Work flow to DR1-1-4	The Distributor Company
DR1-1-4	Send a Copy of the Form to the Factory		DR1-1-3	Work flow to DR1-1-5	Follow-up department
DR1-1-5	Check Quality Tests Reports		DR1-1-4/ Finished Product Quality Analysis Reports	Work flow to DR1-1-6	Quality department
DR1-1-6	Investigating the Complaint and Write a Report	Defectives Verification and Inspection Committee is formed and sent to the complaint location. This committee verifies the defective product to prepare Defectives Verification and Inspection Report and then write Defective Product Returns Document.	DR1-1-5	Defectives Verification and Inspection Report /Defective Product Returns Document/Work flow to DR1-2	The Distributor Company/Warehousing department under the supervision of the Follow-up department
Implementation level two					
process code	process name	Explanation	process inputs	process outputs	responsible department
S1-1-1-1	Determine Required DM Strategic Inventory		Inventory policy/ Supplier performance/ Logistics selection/ P2-4	Work flow to S1-1-1-4	Commercial department with assistance of Warehousing department
S1-1-1-2	Determine Material Required For Production		Bill of Material	Work flow to S1-1-1-4	Commercial department with assistance of Production department
S1-1-1-3	Estimate the Deviation		Historical records of deviation	Work flow to S1-1-1-4	Commercial department
S1-1-1-4	Calculate the Whole DM Required	DM Required = Required DM Strategic Inventory +Material Required For Production + or-Estimated Deviation	S1-1-1-1/ S1-1-1-2/ S1-1-1-3	Work flow to S1-1-1-6	Commercial department

S1-1-1-5	Determine the Available DM Inventory		DM Inventory Balances Daily Reports /S1-4/ M1-2	Work flow to S1-1-1-6	Warehousing department
S1-1-1-6	Identify Schedule Needs from DM	Calculate the needs from DM (Needs from DM= DM Required-Available DM Inventory) then Scheduling the execution of the individual deliveries of direct material needs	S1-1-1-4/ S1-1-1-5	Work flow to S1-1-1-7/ S1-1	Commercial department with assistance of Warehousing department
S1-1-1-7	Prepare Supply Order for DM	Issuing a Supply Order Document (the original is sent to the supplier and a copy is sent to the factory)to order the required material and then managing the execution of the individual deliveries of direct material against the contract and The Supply Order.	S1-1-1-6	Work flow to S1-1/Supply Order Document	Commercial department
S1-1-2-1	Prepare Purchase Order for INDM	Issuing a Purchase Order of the needed INDM describes the quantity and the specifications of this material.	Inventory policy/ Supplier performance/ Logistics selection/ P2-4/INDM Inventory Balances Reports	Work flow to S1-1-2-2 /Purchase Order Document	Engineering department/ Quality department
S1-1-2-2	Prepare Price Quotes	For each item 3 quotes should be submitted unless if there is only one or two suppliers are available for the required item.	S1-1-2-1	Work flow to S1-1-2-3/ Price quotes	Engineering department/ Quality department/ Follow-up department
S1-1-2-3	Discuss and Select the Best Offer	Offers are studied and discussed technically, costs are compared; then the best offer is selected based on certain criteria: (Brand name /Time/Standards/Cost)	S1-1-2-2	Work flow to S1-1-2-4	Engineering department/ Quality department/ Follow-up department
S1-1-2-4	Prepare Supply Order for INDM	Issuing a Supply Order Document (the original is sent to the supplier and a copy is sent to the factory)to order the required material and then managing the execution of the delivery of material against the contract and The Supply Order.	S1-1-2-3	Work flow to S1-1/Supply Order Document	Follow-up department
M1-3-1-1	Sterilization of Water and Raw Materials	The series of activities performed to sterilize Water and Raw Materials	M1-2/ Production and Quality standards	Work flow to M1-3-1/ M1-3-1-2/M1-3-2-1	Quality department

M1-3-1-2	The Filling of sterile water	The series of activities performed to fill the sterile water	M1-2/M1-3-1-1/ Production and Quality standards	Work flow to M1-3-1/ M1-3-2-1/M1-3-2-2	Production department
M1-3-2-1	Quality Control During Production Process	During production, sample is taken from each stage of production to measure the concentration of ozone . This analysis is done hourly over the extended periods of operation. Reference samples are also taken every hour for the bacteriological and chemical analysis to ensure the compliance with standard specifications	M1-3-1/M1-3-1-1/ M1-3-1-2 /Production and Quality standards	Work flow to M1-3-2-2 /M1-4/ Feedback to M1-3-1/M1-3-1-1/ M1-3-1-2	Quality department
M1-3-2-2	Quality Control After Production Process	Sample is taken from the finished product, every hour over the periods of operation, for the bacteriological and chemical analysis to ensure the compliance with standard specifications then tests results are recorded on the following forms: A-Chemical Analysis Results B-Bacteriological Analysis Report C-Finished Product Analysis Report D-Tasting Report	M1-3-1/ M1-3-2-1 /Production and Quality standards	Work flow to M1-5/ Feedback to M1-3-1/ M1-3-1-1, M1-3-1-3 /Finished Product Quality Analysis Reports	Quality department

APPENDIX 6- The bottled water company's SC performance metrics

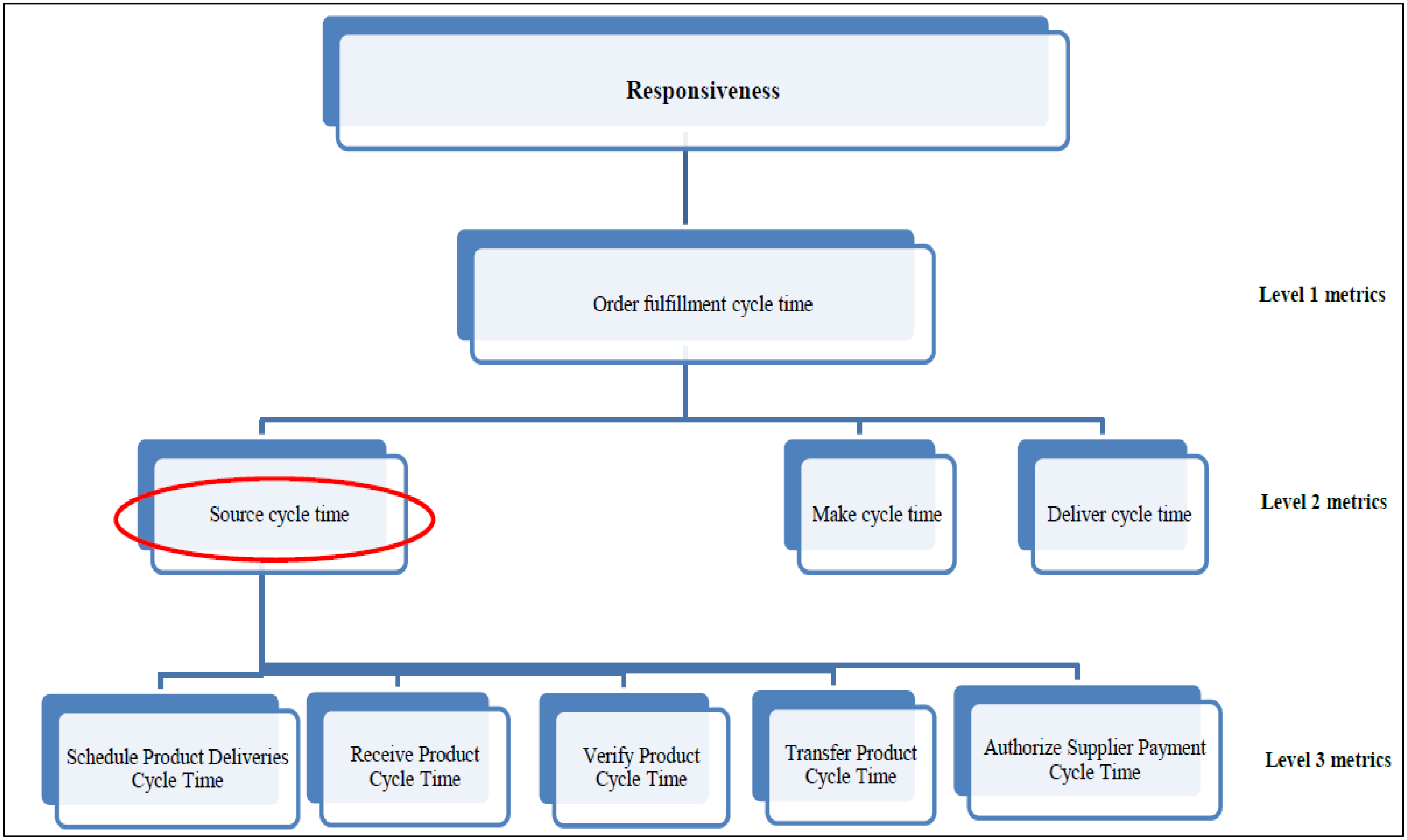
Example:

Figure A6.1 presents an example of the implementation of SCOR model standard performance metrics to measure the performance of a company's entire SC processes. The figure identifies the SCOR "responsiveness" performance measures at different levels of the SCOR hierarchy (level 1 metrics, level 2 metrics and level 3 metrics).

"Order fulfilment cycle time" level 1 performance metrics present the average actual cycle time consistently achieved to fulfil customer orders as an aggregation of the responsiveness sub measures at the lowest levels in the hierarchy. Level 2 metrics measure the average time associated with main processes (source, make and deliver) to fulfil customer orders.

Continuing with the example illustrated in figure A5.2, the SCOR "Source cycle time" performance sub measures are identified in the focal company at level 3 metrics. Accordingly, the average time associated with source processes can be measured as an aggregation of average time associated with all source sub processes (schedule product deliveries, receive product, verify product, transfer product and authorise supplier payment). The calculated average time reflects the performance of source processes in terms of their responsiveness, upon which the company can evaluate the responsiveness of source processes and identify source processes that need improvement in terms of responsiveness.

The bottled water company's SC performance metrics from level 2 metrics through to level 5 metrics are presented in table A6.1.



(Adapted from: SCOR Model - Version 9, Supply Chain Council, 2008)

Figure A6.1: Responsiveness performance measures at different levels of the SCOR hierarchy

Table A6.1: The bottled water company's SC performance metrics from level 2 metrics through to level 5 metrics

Level 2 Metrics				
Performance Attribute Code	Performance Attribute Name	Definition	Calculation	Process
RL.2.1	% of Orders Delivered in Full	Percentage of orders which all of the items are received by customer in the quantities committed	[Total number of orders delivered in full] / [Total number of orders delivered] x 100%	S1.1, S1.2, S1.4, D1.3, D1.7, D1.8, D1.9
RL.2.2	Delivery Performance to Customer Commit Date	The percentage of orders that are fulfilled on the customer's originally scheduled or committed date	[Total number of orders delivered on the original commitment date] / [Total number of orders delivered]x 100%	S1.1, D1.3, D1.8, D1.9
RL.2.3	Perfect Condition	Percentage of orders delivered in an undamaged state that meet specification, have the correct configuration, and accepted by the customer.	[Number of orders delivered in Perfect Condition] / [Number of orders delivered] x 100%	S1.1, S1.2, S1.4, M1.3, M1.4, M1.5 D1.6, D1.7, D1.8, D1.9, SR1, DR1
RL.2.4	Documentation Accuracy	Percentage of orders with accurate documentation supporting the order, including packing slips, bills of lading, invoices, etc.	[Total number of orders delivered with accurate documentation] / [Total number of orders delivered] x 100%	S1,M1, D1,S1.1, S1.2, S1.5, D1.7, D1.10, SR1.3, DR1.1
RL.2.5	Supply Chain Forecast Accuracy	The accuracy of identifying, aggregating, and prioritizing, all sources of demand for the integrated supply chain of a product or service at the appropriate level, horizon and interval.	(Sum Actuals - Sum of Variance) / Sum Actuals to determine percentage error.	P1.1
RL.2.6	Source Forecast Accuracy	The accuracy of identifying, prioritizing, and considering, as a whole with constituent parts, all sources of demand for a product or service in the supply chain.	(Sum Actuals - Sum of Variance) / Sum Actuals to determine percentage error.	P2.1
RL.2.7	Make Forecast Accuracy	The accuracy of identifying, prioritizing, and considering as a whole with constituent parts, all sources of demand in the creation of a product or service.	(Sum Actuals - Sum of Variance) / Sum Actuals to determine percentage error.	P3.1

RL.2.8	Deliver Forecast Accuracy	The accuracy of identifying, prioritizing, and considering, as a whole with constituent parts, all sources of demand in the delivery of a product or service and identifying, evaluating, and considering, as a whole with constituent parts, all things that add value in the delivery of a product or service.	(Sum Actuals - Sum of Variance) / Sum Actuals to determine percentage error.	P4.1, P4.2
RL.2.9	Source Return Forecast Accuracy	The accuracy of The process of identifying, evaluating, and considering, as a whole with constituent parts, all sources of demand for the return of a product.	(Sum Actuals - Sum of Variance) / Sum Actuals to determine percentage error.	P5.1
RL.2.10	Deliver Return Forecast Accuracy	The accuracy of The process of identifying, evaluating, and considering, as a whole with constituent parts, all sources of demand for the return of a product.	(Sum Actuals - Sum of Variance) / Sum Actuals to determine percentage error.	P5.1
RS.2.1	Source Cycle Time	The average time associated with Source Processes.	Source Cycle Time ≈ (Identify Sources of Supply Cycle Time + Select Supplier and Negotiate Cycle Time) + Schedule Product Deliveries Cycle Time + Receive Product Cycle Time + Verify Product Cycle Time +Transfer Product Cycle Time + Authorize Supplier Payment Cycle Time	S1
RS.2.2	Make Cycle Time	The average time associated with Make Processes.	Make Cycle Time ≈ Schedule Production Activities Cycle Time + Issue Material/Product Cycle Time + Produce and Test Cycle Time + Package Cycle Time + Stage Finished Product Cycle Time + Release Finished Product To Deliver Cycle Time	M1
RS.2.3	Deliver Cycle Time	The average time associated with Deliver Processes.	Delivery Cycle Time ≈ MAX {[Receive, Configure, Enter and Validate Order Cycle Time + Reserve Resources & Determine Delivery Date Cycle Time + Select Carriers and Rate Shipments Cycle Time +Receive Product from Make/Source Cycle Time + Pack Product Cycle Time + Load Vehicle & Generate Shipping Documentation Cycle Time + Ship Product Cycle Time + Receive & Verify Product Cycle Time	D1

RS.2.4	Source Return Cycle Time	The average time associated the process of returning material deemed defective by to the last known holder or designated return center. Process includes: customer identification that an action is required and determining what that action should be, communicating with the last known holder, generating return documentation, and physically returning of the excess product.	The average time associated the process of returning material deemed defective by to the last known holder or designated return center. Process includes: customer identification that an action is required and determining what that action should be, communicating with the last known holder, generating return documentation, and physically returning of the excess product.	SR1,
RS.2.5	Deliver Return Cycle Time	The average time associated the process of returning material deemed defective by to the last known holder or designated return center. Process includes: customer identification that an action is required and determining what that action should be, communicating with the last known holder, generating return documentation, and physically returning of the excess product.	The average time associated the process of returning material deemed defective by to the last known holder or designated return center. Process includes: customer identification that an action is required and determining what that action should be, communicating with the last known holder, generating return documentation, and physically returning of the excess product.	DR1
AG.2.1	Upside Source Flexibility	The number of days required to achieve an unplanned sustainable 20% increase in quantity of raw materials.	Least time to pursue all necessary activities.	S1
AG.2.2	Upside Make Flexibility	The number of days required to achieve an unplanned sustainable 20% increase in production with the assumption of no raw material constraints.	Least time to pursue all necessary activities.	M1
AG.2.3	Upside Deliver Flexibility	The number of days required to achieve an unplanned sustainable 20% increase in quantity delivered with the assumption of no other constraints.	Least time to pursue all necessary activities.	D1
AG.2.4	Upside Source Adaptability	The maximum sustainable percentage increase in raw material quantities that can be acquired/received in 30 days.	Least quantity sustainable when considering all components	S1
AG.2.5	Upside Make Adaptability	The maximum sustainable percentage increase in production that can be achieved in 30 days with the assumption of no raw material constraints.	Least quantity sustainable when considering all components	M1
AG.2.6	Upside Deliver Adaptability	The maximum sustainable percentage increase in quantities delivered that can be achieved in 30 days with the assumption of unconstrained finished good availability.	Least quantity sustainable when considering all components	D1

AG.2.7	Downside Source Adaptability	The raw material quantity reduction sustainable at 30 days prior to delivery with no inventory or cost penalties.	Least quantity reduction sustainable when considering all components	S1
AG.2.8	Downside Make Adaptability	The production reduction sustainable at 30 days prior to delivery with no inventory or cost penalties.	Least quantity reduction sustainable when considering all components	M1
AG.2.9	Downside Deliver Adaptability	The reduction in delivered quantities sustainable at 30 days prior to delivery with no inventory or cost penalties.	Least quantity reduction sustainable when considering all components	D1
CO.2.1	Freight expense		Freight expense	D1
CO.2.2	Direct marketing expense		Direct marketing expense	D1
CO.2.3	Direct sales expense		Direct sales expense	D1
CO.2.4	Administrative expense		Administrative expense= overhead+ bank charges+ warehouses+ bad debt+ any other cost related to the administration processes	P, S1, D1, SR1, DR1
CO.2.5	Cost to Make	The cost associated with buying raw materials and producing finished goods. This cost includes direct costs (labor, materials) and indirect costs (overhead).	Cost to Make = Sum of Material, Labor, and Direct non-Material Product-related Cost (equipment) and of Indirect Product-related Cost	M1
AM.2.1	Days Sales Outstanding	The length of time from when a sale is made until cash for it is received from customers. The amount of sales outstanding expressed in days.	The [average of gross accounts receivable (AR)] / [total gross annual sales / 365].	D1.10
AM.2.2	Inventory Days of Supply	The amount of inventory (stock) expressed in days of sales	The [average of gross value of inventory at standard cost] / [annual cost of goods sold (COGS) / 365]	S1,M1.1,M1.2, M1.5, D1.3, D1.5
AM.2.3	Days Payable Outstanding	The length of time from purchasing materials, labor and/or conversion resources until cash payments must be made expressed in days.	The [average of gross accounts payable (AP)] / [total gross annual material purchases / 365].	S1.5
AM.2.4	Operating Rate	Actual manufacturing output to potential full capacity output.	OR = (AO /PO) x 100 OR is the operating rate. AO is Actual Output and PO is potential output within the measurement period. The final number is a percentage of the potential output of 100%.	M1.1, M1.3, M1.4

AM.2.5	Downtime	Downtime is a period when a system is unavailable and fails to provide or perform its primary function.	Downtime = scheduled Downtime + Unscheduled Downtime	M1.1, M1.3, M1.4
AM.2.6	% spoilage Material	The proportion of spoilage of materials issued for production.	[The amount of spoilage of materials issued for production] / [Total material issued to production within the measurement period] x 100%	M1.1, M1.3, M1.4
Level 3 Metrics				
Performance Attribute Code	Performance Attribute Name	Definition	Calculation	Process
RL.3.1	Delivery Item Accuracy	All items ordered are the items actually provided, and no extra items are provided	[Total number of orders delivered in Item Accuracy] / [Total number of orders delivered] x 100%	S1.1, S1.2, S1.4, D1.3, D1.7, D1.8, D1.9
RL.3.2	Delivery Quantity Accuracy	All quantities received by the customer match the order quantities (within mutually agreed tolerances)	[Total number of orders delivered in Quantity Accuracy] / [Total number of orders delivered] x 100%	S1.1, S1.2, S1.4, D1.3, D1.7, D1.8, D1.10
RL.3.3	Customer Commit Date Achievement Time Customer Receiving	The order is received on time as defined by the customer	[Total number of orders is received on time as defined by the customer] / [Total number of orders delivered] x 100%	S1.1, S1.2, S1.4, D1.3, D1.8, D1.9
RL.3.4	Delivery Location Accuracy	The delivery is made to the correct location and Customer entity	[Total number of orders is made to the correct location and Customer entity] / [Total number of orders delivered] x 100%	D1.3, D1.8, D1.10
RL.3.5	Orders Delivered Damage Free Conformance	Percentage of orders delivered in an undamaged state , and accepted by the customer	[Number of orders delivered damage Free] / [Number of orders delivered] x 100%	S1.1, S1.2, S1.4, M1.3, M1.4, M1.5, D1.6, D1.7, D1.8, D1.9
RL.3.6	Orders Delivered Defect Free Conformance	Percentage of orders delivered in an undefected state , and accepted by the customer	[Number of orders delivered defect Free] / [Number of orders delivered] x 100%	S1.1, S1.2, S1.4, M1.3, M1.4, M1.5 D1.6, D1.7, D1.8, D1.9
RL.3.7	% Return	% Return to sales at any level of merchandise hierarchy	[Number of orders returned] / [Number of orders delivered] x 100%	SR1, DR1

RL.3.8	Shipping Documentation Accuracy	Percentage of orders with complete, correct, and readily available shipping documents when and how expected by the customer, Government and other supply chain regulatory entities.	The number of orders / lines that are received on-time with correct shipping documents divided by the total orders / lines processed in the measurement period % Orders/ Lines Received with Correct Shipping Documents [Total number of orders delivered with accurate shipping documents] / [Total number of orders delivered] x 100%	S1.1, S1.2, D1.7
RL.3.9	Compliance Documentation Accuracy	Percentage of complaince documents are complete, correct, and readily available when and how expected by the customer, Government and other supply chain regulatory entities.	[Total number of returned delivered orders with accurate complaince documents] / [Total number of returned delivered orders] x 100%	SR1.3, DR1.1
RL.3.10	Other Required Documentation Accuracy	Percentage of orders with the complete, correct, and readily available required quality certification when and how expected by the customer, Government and other supply chain regulatory entities.	Total number of NCRs	S1,M1, D1
RL.3.11	Payment Documentation Accuracy	Percentage of orders with complete, correct, and readily available payment documents when and how expected by the customer, Government and other supply chain regulatory entities.	[Total number of orders delivered with accurate payment documents] / [Total number of orders delivered] x 100%	S1.5, D1.10
RS.3.1	Identify Sources of Supply Cycle Time	The average time associated with Identify Sources of Supply Processes.	Identify Sources of Supply Cycle Time	S1.1
RS.3.2	Select Supplier and Negotiate Cycle Time	The average time associated with Select Supplier and Negotiate Processes.	Select Supplier and Negotiate Cycle Time	S1.1
RS.3.3	Schedule Product Deliveries Cycle Time	The average time associated with Schedule Product Deliveries Processes.	Schedule Product Deliveries Cycle Time	S1.1
RS.3.4	Receive Product Cycle Time	The average time associated with Receive Product Processes.	Receive Product Cycle Time	S1.2
RS.3.5	Verify Product Cycle Time	The average time associated with Verify Product Processes.	Verify Product Cycle Time	S1.3
RS.3.6	Transfer Product Cycle Time	The average time associated with Transfer Product Processes.	Transfer Product Cycle Time	S1.4

RS.3.7	Authorize Supplier Payment Cycle Time	The average time associated with Authorize Supplier Payment Processes.	Authorize Supplier Payment Cycle Time	S1.5
RS.3.8	Schedule Production Activities Cycle Time	The average time associated with Schedule Production Activities Processes.	Schedule Production Activities Cycle Time	M1
RS.3.9	Issue Material Cycle Time	The average time associated with Issue Material Processes.	Issue Material/ Product Cycle Time	M2
RS.3.10	Produce and Test Cycle Time	The average time associated with Schedule Product Deliveries Processes.	Produce and Test Cycle Time	M3
RS.3.11	Package Cycle Time	The average time associated with Package Processes.	Package Cycle Time	M4
RS.3.12	Stage Finished Product Cycle Time	The average time associated with Stage Finished Product Processes.	Stage Finished Product Cycle Time	M5
RS.3.13	Release Finished Product To Deliver Cycle Time	The average time associated with Release Finished Product To Deliver Processes.	Release Finished Product To Deliver Cycle Time	M6
RS.3.14	Receive and validate order +Determining delivery date	The average time associated with Processes+ The average time associated with Reserve Resources & Determine Delivery Date Processes.	Receive, Configure, Enter and Validate Order Cycle Time + Reserve Resources & Determine Delivery Date Cycle Time	D1.2, D1.3
RS.3.15	Receive product from warehouse +Pack product + Load vehicle	The average time associated with Receive Product from Make Processes. +The average time associated with Pack Product Processes. +The average time associated with Load Vehicle & Generate Shipping Documentation Processes.	Receive Product from Make Cycle Time+ Pack Product Cycle Time+ Load Vehicle & Generate Shipping Documentation Cycle Time	D1.5, D1.6, D1.7
RS.3.16	Ship Product Cycle Time	The average time associated with Ship Product Processes.	Ship Product Cycle Time	D1.8
RS.3.17	Receive & Verify Product Cycle Time	The average time associated with Receive & Verify Product Processes.	Receive & Verify Product Cycle Time	D1.9
CO.3.1	M Cost	The M cost associated with buying raw materials and producing finished goods.	M Cost = DM + fuel +spare parts+ packaging+ any other cost related to material	M1
CO.3.2	L Cost	The L cost associated with making product and producing finished goods.	L Cost = permanent labor + temporary labor	M1

CO.3.3	Indirect Costs Related To Making Product	The Indirect costs (overhead) associated with making product and producing finished goods.	Indirect Costs Related To Making Product	M1
AM.3.1	Scheduled Downtime	Scheduled downtime is planned downtime that is included in the design of the system.	Scheduled Downtime = Scheduled Process Downtime + Scheduled Equipment Downtime	M1.1, M1.3, M1.4
AM.3.2	Unscheduled Downtime	Unscheduled downtime is unplanned downtime due to system or environmental failures.	Unscheduled Downtime = Unscheduled Process Downtime + Unscheduled Equipment Downtime	M1.1, M1.3, M1.4
Level 4 Metrics				
Performance Attribute Code	Performance Attribute Name	Definition	Calculation	Process
RL.4.1	% Orders Processed With The Item Accuracy	Percentage of orders which all of the items are received from supplier.	[Total number of orders that are processed with the item accuracy] / [Total number of orders processed within the measurement period] x 100%	S1.1, S1.2
RL.4.2	% Product Transferred without Item Errors	Percentage of material transferred transactions processed without item error.	[Total number of transactions processed without item error] / [Total number of transactions processed within the measurement period] x 100%	S1.4
RL.4.3	% of Orders Delivered With The Item Accuracy	Percentage of orders which all of the items are delivered to customer.	[Total number of orders that are delivered with the item accuracy] / [Total number of orders delivered within the measurement period] x 100%	D1.3, D1.7, D1.8, D1.9
RL.4.4	% Orders Processed With The Quantity Accuracy	Percentage of orders which are received from supplier in the quantities committed.	[Total number of orders that are processed with the quantity accuracy] / [Total number of orders processed within the measurement period] x 100%	S1.1, S1.2
RL.4.5	% Product Transferred without Quantity Errors	Percentage of material transferred transactions processed without quantity error.	[Total number of transactions processed without quantity error] / [Total number of transactions processed within the measurement period] x 100%	S1.4

RL.4.6	% of Orders Delivered With The Quantity Accuracy	Percentage of orders which are delivered to customer in the quantities committed.	[Total number of orders that are delivered with the quantity accuracy] / [Total number of orders delivered within the measurement period] x 100%	D1.3, D1.7, D1.8, D1.9
RL.4.7	% of Orders Processed on time	Percentage of orders which are received from supplier on the time committed.	[Total number of orders that are processed on time] / [Total number of orders processed within the measurement period] x 100%	S1.1, S1.2
RL.4.8	% Product Transferred On-Time to Demand Requirement	Percentage of product orders that are transferred on-time to demand requirements.	[Total number of product orders that are transferred on-time to demand requirements] / [Total number of orders delivered]x 100%	S1.4
RL.4.9	% of Orders Delivered on time	Percentage of orders which are delivered to customer on the time committed.	[Total number of orders that are delivered on time] / [Total number of orders delivered within the measurement period] x 100%	D1.3, D1.8, D1.9
RL.4.10	% of Orders Processed Damage Free	Percentage of orders which are received from supplier in an undamaged state.	[Total number of orders that are processed damage free] / [Total number of orders processed within the measurement period] x 100%	S1.1, S1.2
RL.4.11	% Product Transferred Damage Free to Demand Requirement	Percentage of product orders that are transferred in an undamaged state to demand requirements.	[Total number of product orders that are transferred damage free to demand requirements] / [Total number of orders delivered]x 100%	S1.4
RL.4.12	% of Orders Delivered Damage Free	Percentage of orders which are delivered to customer in an undamaged state.	[Total number of orders that are delivered damage free] / [Total number of orders delivered within the measurement period] x 100%	M1.3, M1.4, M1.5 D1.6, D1.7, D1.8, D1.9
RL.4.13	% of Orders Processed Defect Free	Percentage of orders which are received from supplier in an undefected state.	[Total number of orders that are processed defect free] / [Total number of orders processed within the measurement period] x 100%	S1.1, S1.2

RL.4.14	% Product Transferred Defect Free to Demand Requirement	Percentage of product orders that are transferred in an undefected state to demand requirements.	[Total number of product orders that are transferred defect free to demand requirements] / [Total number of orders delivered]x 100%	S1.4
RL.4.15	% of Orders Delivered Defect Free	Percentage of orders which are delivered to customer in an undefected state.	[Total number of orders that are delivered defect free] / [Total number of orders delivered within the measurement period] x 100%	M1.3, M1.4, M1.5 D1.6, D1.7, D1.8, D1.9
RL.4.16	% Source Return	% of returned processed order.	[Total number of returned processed order] / [Total number of orders processed within the measurement period] x 100%	SR1
RL.4.17	% Deliver Return	% of returned delivered order	[Total number of returned delivered order] / [Total number of orders delivered within the measurement period] x 100%	DR1
RL.4.18	% Orders Received with Correct Shipping Documents	% of orders that are received with correct shipping documents.	[Total number of orders that are received with correct shipping documents] / [Total number of orders processed in the measurement period] x 100%	S1.1, S1.2
RL.4.19	% Orders Delivered with Correct Shipping Documents	% of orders that are delivered to customer with correct shipping documents.	[Total number of orders that are delivered with correct shipping documents] / [Total number of orders delivered within the measurement period] x 100%	D1.7
RL.4.20	% Orders Returned to Source with Correct Complaince Documents	Percentage of orders that are returned to source with correct complaince documents.	[Total number of orders that are returned to source with correct complaince documents] / [Total number of orders processed in the measurement period] x 100%	SR1.3
RL.4.21	% Orders Returned with Correct Complaince Documents	Percentage of returned delivered orders that are returned with correct complaince documents.	[Total number of returned delivered orders that are returned with correct complaince documents] / [Total number of orders delivered within the measurement period] x 100%	DR1.1
RL.4.22	% Orders Received with Correct Payment Documents	% of orders that are received with correct payment documents.	[Total number of orders that are received with correct payment documents] / [Total number of orders processed in the measurement period] x 100%	S1.5

RL.4.23	% Orders Delivered with Correct Payment Documents	% of orders that are delivered to customer with correct payment documents.	[Total number of orders that are delivered with correct payment documents] / [Total number of orders delivered within the measurement period] x 100%	D1.10
RS.4.1	Identify DM Sources of Supply Cycle Time	The average time associated with Identify DM Sources of Supply Processes.	Identify DM Sources of Supply Cycle Time	S1.1.1
RS.4.2	Identify INDM Sources of Supply Cycle Time	The average time associated with Identify INDM Sources of Supply Processes.	Identify INDM Sources of Supply Cycle Time	S1.1.2
RS.4.3	Select DM Supplier and Negotiate Cycle Time	The average time associated with Select DM Supplier and Negotiate Processes.	Select DM Supplier and Negotiate Cycle Time	S1.1.1
RS.4.4	Select INDM Supplier and Negotiate Cycle Time	The average time associated with Select INDM Supplier and Negotiate Processes.	Select INDM Supplier and Negotiate Cycle Time	S1.1.2
RS.4.5	Schedule DM Product Deliveries Cycle Time	The average time associated with Schedule DM Product Deliveries Processes.	Schedule DM Product Deliveries Cycle Time	S1.1.1
RS.4.6	Schedule INDM Product Deliveries Cycle Time	The average time associated with Schedule INDM Product Deliveries Processes.	Schedule INDM Product Deliveries Cycle Time	S1.1.2
RS.4.7	Receive DM Product Cycle Time	The average time associated with Receive DM Product Processes.	Receive DM Product Cycle Time	S1.2
RS.4.8	Receive INDM Product Cycle Time	The average time associated with Receive INDM Product Processes.	Receive INDM Product Cycle Time	S1.2
RS.4.9	Verify DM Product Cycle Time	The average time associated with Verify DM Product Processes.	Verify DM Product Cycle Time	S1.3
RS.4.10	Verify INDM Product Cycle Time	The average time associated with Verify INDM Product Processes.	Verify INDM Product Cycle Time	S1.3
RS.4.11	Transfer DM Product Cycle Time	The average time associated with Transfer DM Product Processes.	Transfer DM Product Cycle Time	S1.4

RS.4.12	Transfer INDM Product Cycle Time	The average time associated with Transfer INDM Product Processes.	Transfer INDM Product Cycle Time	S1.4
RS.4.13	Authorize DM Supplier Payment Cycle Time	The average time associated with Authorize DM Supplier Payment Processes.	Authorize DM Supplier Payment Cycle Time	S1.5
RS.4.14	Authorize INDM Supplier Payment Cycle Time	The average time associated with Authorize INDM Supplier Payment Processes.	Authorize INDM Supplier Payment Cycle Time	S1.5
AM.4.1	Scheduled Process Downtime	The period of downtime which not officially scheduled in the production plan.	The amount of downtime officially scheduled in the production plan.	M1.1, M1.3, M1.4
AM.4.2	Scheduled Equipment Downtime	A period of time when the equipment is not available to perform its intended function due to planned downtime events. These include maintenance delay (delay after an interrupt is reported, but before anyone arrives to repair it); production test; preventive maintenance; change of consumables; setup; and facilities-related downtime.	The amount of time when the equipment is not available to perform its intended function due to planned downtime events.	M1.1, M1.3, M1.4
AM.4.3	Unscheduled Process Downtime	The period of downtime which not officially scheduled in the production plan.	The amount of downtime which not officially scheduled in the production plan.	M1.1, M1.3, M1.4
AM.4.4	Unscheduled Equipment Downtime	A period of time when the equipment is not available to perform its intended function due to unplanned downtime events. These include maintenance delay, repair, change of consumables, out-of-spec input, and facilities-related downtime	The amount of time when the equipment is not available to perform its intended function due to unplanned downtime events.	M1.1, M1.3, M1.4
Level 5 Metrics				
Performance Attribute Code	Performance Attribute Name	Definition	Calculation	Process
RL.5.1	% Of DM Orders Processed With The Item Accuracy	Percentage of DM orders which all of the items are received from supplier.	[Total number of DM orders that are processed with the item accuracy] / [Total number of DM orders processed within the measurement period] x 100%	S1.1.1, S1.2
RL.5.2	% Of INDM Orders Processed With The Item Accuracy	Percentage of INDM orders which all of the items are received from supplier.	[Total number of INDM orders that are processed with the item accuracy] / [Total number of INDM orders processed within the measurement period] x 100%	S1.1.2, S1.2

RL.5.3	% Of DM Orders Processed With The Quantity Accuracy	Percentage of DM orders which are received from supplier in the quantities committed.	[Total number of DM orders that are processed with the quantity accuracy] / [Total number of DM orders processed within the measurement period] x 100%	S1.1.1, S1.2
RL.5.4	% Of INDM Orders Processed With The Quantity Accuracy	Percentage of INDM orders which are received from supplier in the quantities committed.	[Total number of INDM orders that are processed with the quantity accuracy] / [Total number of INDM orders processed within the measurement period] x 100%	S1.1.2, S1.2
RL.5.5	% of DM Orders Processed on time	Percentage of DM orders which are received from supplier on the time committed.	[Total number of DM orders that are processed on time] / [Total number of DM orders processed within the measurement period] x 100%	S1.1.1, S1.2
RL.5.6	% of INDM Orders Processed on time	Percentage of INDM orders which are received from supplier on the time committed.	[Total number of INDM orders that are processed on time] / [Total number of INDM orders processed within the measurement period] x 100%	S1.1.2, S1.2
RL.5.7	% of DM Orders Processed Damage Free	Percentage of DM orders which are received from supplier in an undamaged state.	[Total number of DM orders that are processed damage free] / [Total number of DM orders processed within the measurement period] x 100%	S1.1.1, S1.2
RL.5.8	% of INDM Orders Processed Damage Free	Percentage of INDM orders which are received from supplier in an undamaged state.	[Total number of INDM orders that are processed damage free] / [Total number of INDM orders processed within the measurement period] x 100%	S1.1.2, S1.2
RL.5.9	% of DM Orders Processed Defect Free	Percentage of DM orders which are received from supplier in an undefected state.	[Total number of DM orders that are processed defect free] / [Total number of DM orders processed within the measurement period] x 100%	S1.1.1, S1.2
RL.5.10	% of INDM Orders Processed Defect Free	Percentage of INDM orders which are received from supplier in an undefected state.	[Total number of INDM orders that are processed defect free] / [Total number of INDM orders processed within the measurement period] x 100%	S1.1.2, S1.2
RL.5.11	% DM Source Return	% of DM returned processed order.	[Total number of DM returned processed order] / [Total number of DM orders processed within the measurement period] x 100%	SR1

RL.5.12	% INDM Source Return	% of INDM returned processed order.	[Total number of INDM returned processed order] / [Total number of INDM orders processed within the measurement period] x 100%	SR1
RL.5.13	% DM Orders Received with Correct Shipping Documents	% of DM orders that are received with correct shipping documents.	[Total number of DM orders that are received with correct shipping documents] / [Total number of DM orders processed in the measurement period] x 100%	S1.1.1, S1.2
RL.5.14	% INDM Orders Received with Correct Shipping Documents	% of INDM orders that are received with correct shipping documents.	[Total number of INDM orders that are received with correct shipping documents] / [Total number of INDM orders processed in the measurement period] x 100%	S1.1.2, S1.2
RL.5.15	% DM Orders Returned to Source with Correct Complaince Documents	Percentage of DM orders that are returned to source with correct complaince documents.	[Total number of DM orders that are returned to source with correct complaince documents] / [Total number of orders processed in the measurement period] x 100%	SR1.3
RL.5.16	% INDM Orders Returned to Source with Correct Complaince Documents	Percentage of INDM orders that are returned to source with correct complaince documents.	[Total number of INDM orders that are returned to source with correct complaince documents] / [Total number of orders processed in the measurement period] x 100%	SR1.3
RL.5.17	% DM Orders Received with Correct Payment Documents	% of DM orders that are received with correct payment documents.	[Total number of DM orders that are received with correct payment documents] / [Total number of DM orders processed in the measurement period] x 100%	S1.5
RL.5.18	% INDM Orders Received with Correct Payment Documents	% of INDM orders that are received with correct payment documents.	[Total number of INDM orders that are received with correct payment documents] / [Total number of INDM orders processed in the measurement period] x 100%	S1.5
RS 5-1	Identify machines Sources of Supply Cycle Time	The average time associated with Identify machines Sources of Supply Processes.	Identify machines Sources of Supply Cycle Time	S1.1.2
RS 5-2	Identify other INDM Sources of Supply Cycle Time	The average time associated with Identify other INDM Sources of Supply Processes.	Identify other INDM Sources of Supply Cycle Time	S1.1.2

APPENDIX 7- The measurement procedures to determine the relative weights of the bottled water company's SC performance measures

Appendix 7.1- The pair-wise questionnaire's responses

Appendix 7.2- The aggregate pair-wise comparison matrix

Appendix 7.3- The relative weights of the bottled water company's SC performance measures

Appendix 7.4- The consistency test

Appendix 7.1- The pair-wise questionnaire's responses

Table A7.1: The pair-wise questionnaire's responses to determine the relative weights of the bottled water company's SC performance measures

SC performance measures	Experts' responses				Fuzzy pair-wise comparison matrix			uncertainty level		aggregate pair-wise comparison matrix		
Supply Chain Reliability	EXP.1	EXP.2	EXP.3	EXP.4	MIN (L)	GEOMEAN (M)	MAX (U)	α	λ	L_{ij}^{α}	U_{ij}^{α}	Aggregation
RL												
RL1-1 VS RL1-2	1	1	0.2	0.3333	0.2	0.50812	1	0.5	0.5	0.35406002	0.754060022	0.554060022
RL1-1												
RL2-1 VS RL2-2	5	1	1	3	1	1.96799	5	0.5	0.5	1.48399484	3.483994836	2.483994836
RL2-1 VS RL2-3	1	0.2	0.1111	0.2	0.1111	0.258192	1	0.5	0.5	0.18464622	0.629096217	0.406871217
RL2-1 VS RL2-4	5	5	1	1	1	2.236068	5	0.5	0.5	1.61803399	3.618033989	2.618033989
RL2-2 VS RL2-3	0.3333	0.2	0.1111	0.2	0.1111	0.196179	0.3333	0.5	0.5	0.15363946	0.26473946	0.20918946
RL2-2 VS RL2-4	1	5	0.2	1	0.2	1	5	0.5	0.5	0.6	3	1.8
RL2-3 VS RL2-4	7	5	5	9	5	6.299704	9	0.5	0.5	5.64985197	7.649851967	6.649851967
RL1-2												
RL2-5 VS RL2-6	0.3333	7	1	3	0.3333	1.626536	7	0.5	0.5	0.97991795	4.313267948	2.646592948
RL2-5 VS RL2-7	0.1479	1	1	1	0.1479	0.620143	1	0.5	0.5	0.38402164	0.810071641	0.597046641
RL2-5 VS RL2-8	0.1479	1	1	5	0.1479	0.927331	5	0.5	0.5	0.53761525	2.963665251	1.750640251
RL2-5 VS RL2-9	0.3333	5	1	0.2	0.2	0.759817	5	0.5	0.5	0.47990834	2.879908345	1.679908345
RL2-5 VS RL2-10	0.2	1	1	0.3333	0.2	0.50812	1	0.5	0.5	0.35406002	0.754060022	0.554060022
RL2-6 VS RL2-7	1	1	1	1	1	1	1	0.5	0.5	1	1	1
RL2-6 VS RL2-8	1	1	3	1	1	1.316074	3	0.5	0.5	1.15803701	2.158037006	1.658037006
RL2-6 VS RL2-9	7	5	1	3	1	3.201086	7	0.5	0.5	2.10054294	5.100542936	3.600542936
RL2-6 VS RL2-10	1	1	1	1	1	1	1	0.5	0.5	1	1	1
RL2-7 VS RL2-8	1	1	3	1	1	1.316074	3	0.5	0.5	1.15803701	2.158037006	1.658037006
RL2-7 VS RL2-9	5	5	3	7	3	4.78674	7	0.5	0.5	3.89336993	5.893369929	4.893369929
RL2-7 VS RL2-10	3	1	3	7	1	2.817313	7	0.5	0.5	1.90865662	4.908656624	3.408656624

RL2-8 VS RL2-9	5	5	1	5	1	3.343702	5	0.5	0.5	2.17185076	4.171850762	3.171850762
RL2-8 VS RL2-10	1	1	1	5	1	1.495349	5	0.5	0.5	1.24767439	3.247674391	2.247674391
RL2-9 VS RL2-10	0.1479	0.2	0.2	1	0.1479	0.277337	1	0.5	0.5	0.21261825	0.638668253	0.425643253
RL2-1												
RL3-1 VS RL3-2	1	1	1	7	1	1.626577	7	0.5	0.5	1.31328828	4.313288281	2.813288281
RL2-2												
RL3-3 VS RL3-4	5	1	1	1	1	1.495349	5	0.5	0.5	1.24767439	3.247674391	2.247674391
RL2-3												
RL3-5 VS RL3-6	7	7	1	0.1111	0.1111	1.527487	7	0.5	0.5	0.81929352	4.263743521	2.541518521
RL3-5 VS RL3-7	1	7	1	7	1	2.645751	7	0.5	0.5	1.82287566	4.822875656	3.322875656
RL3-6 VS RL3-7	0.2	7	1	9	0.2	1.884051	9	0.5	0.5	1.04202546	5.44202546	3.24202546
RL2-4												
RL3-8 VS RL3-9	0.1111	1	0.3333	0.2	0.1111	0.293356	1	0.5	0.5	0.20222796	0.646677955	0.424452955
RL3-8 VS RL3-10	7	1	0.3333	1	0.3333	1.2359	7	0.5	0.5	0.78460001	4.117950009	2.451275009
RL3-8 VS RL3-11	5	1	1	1	1	1.495349	5	0.5	0.5	1.24767439	3.247674391	2.247674391
RL3-9 VS RL3-10	9	1	1	1	1	1.732051	9	0.5	0.5	1.3660254	5.366025404	3.366025404
RL3-9 VS RL3-11	9	5	5	0.2	0.2	2.59002	9	0.5	0.5	1.39501003	5.795010032	3.595010032
RL3-10 VS RL3-11	0.3333	5	5	0.2	0.2	1.136191	5	0.5	0.5	0.66809548	3.06809548	1.86809548
RL3-1												
RL4-1 VS RL4-2	5	5	5	5	5	5	5	0.5	0.5	5	5	5
RL4-1 VS RL4-3	0.1111	1	0.3333	1	0.1111	0.438669	1	0.5	0.5	0.2748847	0.719334701	0.497109701
RL4-2 VS RL4-3	0.1111	0.2	0.2	0.1479	0.1111	0.160116	0.2	0.5	0.5	0.13560815	0.180058152	0.157833152
RL3-2												
RL4-4 VS RL4-5	5	5	1	1	1	2.236068	5	0.5	0.5	1.61803399	3.618033989	2.618033989
RL4-4 VS RL4-6	0.1111	1	1	0.1429	0.1111	0.354966	1	0.5	0.5	0.23303292	0.677482925	0.455257925
RL4-5 VS RL4-6	0.1111	0.2	1	1	0.1111	0.386088	1	0.5	0.5	0.24859387	0.693043871	0.470818871

RL3-3												
RL4-7 VS RL4-8	5	5	7	5	5	5.438787	7	0.5	0.5	5.21939326	6.219393265	5.719393265
RL4-7 VS RL4-9	0.1111	1	1	1	0.1111	0.577336	1	0.5	0.5	0.34421792	0.788667917	0.566442917
RL4-8 VS RL4-9	0.1111	0.2	0.1429	0.1429	0.1111	0.145949	0.2	0.5	0.5	0.12852467	0.172974669	0.150749669
RL3-5												
RL4-10 VS RL4-11	5	1	7	5	1	3.637136	7	0.5	0.5	2.31856788	5.318567881	3.818567881
RL4-10 VS RL4-12	0.1111	1	1	1	0.1111	0.577336	1	0.5	0.5	0.34421792	0.788667917	0.566442917
RL4-11 VS RL4-12	0.1111	1	0.1111	0.1429	0.1111	0.204935	1	0.5	0.5	0.15801725	0.602467252	0.380242252
RL3-6												
RL4-13 VS RL4-14	5	1	7	7	1	3.956321	7	0.5	0.5	2.4781605	5.478160499	3.978160499
RL4-13 VS RL4-15	0.1111	1	1	1	0.1111	0.577336	1	0.5	0.5	0.34421792	0.788667917	0.566442917
RL4-14 VS RL4-15	0.1111	1	0.1429	0.2	0.1111	0.23738	1	0.5	0.5	0.17423999	0.618689985	0.396464985
RL3-7												
RL4-16 VS RL4-17	0.1479	1	1	0.1429	0.1429	0.381285	1	0.5	0.5	0.26209267	0.690642667	0.476367667
RL3-8												
RL4-18 VS RL4-19	0.1479	1	1	1	0.1479	0.620143	1	0.5	0.5	0.38402164	0.810071641	0.597046641
RL3-9												
RL4-20 VS RL4-21	0.1111	1	1	0.1429	0.1111	0.354966	1	0.5	0.5	0.23303292	0.677482925	0.455257925
RL3-11												
RL4-22 VS RL4-23	1	1	1	1	1	1	1	0.5	0.5	1	1	1
RL4-1												
RL5-1 VS RL5-2	7	1	3	0.3333	0.3333	1.626536	7	0.5	0.5	0.97991795	4.313267948	2.646592948
RL4-4												
RL5-3 VS RL5-4	7	1	7	0.1429	0.1429	1.626699	7	0.5	0.5	0.88479927	4.313349271	2.599074271
RL4-7												

RL5-5 VS RL5-6	0.2	1	5	0.1429	0.1429	0.614834	5	0.5	0.5	0.37886713	2.807417128	1.593142128
RL4-10												
RL5-7 VS RL5-8	7	1	0.2	0.1429	0.1429	0.66879	7	0.5	0.5	0.40584523	3.834395227	2.120120227
RL4-13												
RL5-9 VS RL5-10	7	1	0.1429	0.2	0.1429	0.66879	7	0.5	0.5	0.40584523	3.834395227	2.120120227
RL4-16												
RL5-11 VS RL5-12	7	1	0.1429	0.2	0.1429	0.66879	7	0.5	0.5	0.40584523	3.834395227	2.120120227
RL4-18												
RL5-13 VS RL5-14	1	1	0.1429	0.2	0.1429	0.411164	1	0.5	0.5	0.27703222	0.705582224	0.491307224
RL4-20												
RL5-15 VS RL5-16	1	1	0.1429	1	0.1429	0.614834	1	0.5	0.5	0.37886713	0.807417128	0.593142128
RL4-22												
RL5-17 VS RL5-18	3	1	1	0.1429	0.1429	0.809167	3	0.5	0.5	0.47603369	1.904583694	1.190308694
SC performance measures	**Experts' responses**				**Fuzzy pair-wise comparison matrix**			**uncertainty level**		**aggregate pair-wise comparison matrix**		
Supply Chain Responsiveness	**EXP.1**	**EXP.2**	**EXP.3**	**EXP.4**	**MIN (L)**	**GEOMEAN (M)**	**MAX (U)**	α	λ	L_{ij}^{α}	U_{ij}^{α}	**Aggregation**
RS												
RS1-1 VS RS1-2	7	3	3	7	3	4.582576	7	0.5	0.5	3.79128785	5.791287847	4.791287847
RS1-1												
RS2-1 VS RS2-2	0.1479	1	0.1429	0.2	0.1429	0.254981	1	0.5	0.5	0.19894044	0.627490435	0.413215435
RS2-1 VS RS2-3	0.1479	1	1	0.2	0.1479	0.414715	1	0.5	0.5	0.2813074	0.707357404	0.494332404
RS2-2 VS RS2-3	0.2	1	1	1	0.2	0.66874	1	0.5	0.5	0.43437015	0.834370152	0.634370152
RS1-2												
RS2-4 VS RS2-5	0.1111	0.2	0.1429	1	0.1111	0.23738	1	0.5	0.5	0.17423999	0.618689985	0.396464985
RS2-1												
RS3-1 VS RS3-2	1	1	1	0.2	0.2	0.66874	1	0.5	0.5	0.43437015	0.834370152	0.634370152
RS3-1 VS RS3-3	1	0.2	1	0.2	0.2	0.447214	1	0.5	0.5	0.3236068	0.723606798	0.523606798

RS3-1 VS RS3-4	1	0.2	0.3333	0.1429	0.1429	0.31241	1	0.5	0.5	0.2276548	0.656204805	0.441929805
RS3-1 VS RS3-5	3	0.2	1	0.1429	0.1429	0.541123	3	0.5	0.5	0.34201142	1.770561423	1.056286423
RS3-1 VS RS3-6	3	1	0.3333	0.2	0.2	0.668724	3	0.5	0.5	0.43436179	1.834361793	1.134361793
RS3-1 VS RS3-7	0.3333	0.2	3	0.2	0.2	0.447202	3	0.5	0.5	0.32360121	1.723601207	1.023601207
RS3-2 VS RS3-3	1	0.2	1	0.2	0.2	0.447214	1	0.5	0.5	0.3236068	0.723606798	0.523606798
RS3-2 VS RS3-4	1	0.2	1	0.2	0.2	0.447214	1	0.5	0.5	0.3236068	0.723606798	0.523606798
RS3-2 VS RS3-5	3	0.2	0.3333	0.2	0.2	0.447202	3	0.5	0.5	0.32360121	1.723601207	1.023601207
RS3-2 VS RS3-6	3	1	3	0.2	0.2	1.158292	3	0.5	0.5	0.67914609	2.079146093	1.379146093
RS3-2 VS RS3-7	0.3333	0.2	1	0.2	0.2	0.3398	1	0.5	0.5	0.26990018	0.669900177	0.469900177
RS3-3 VS RS3-4	1	1	1	0.2	0.2	0.66874	1	0.5	0.5	0.43437015	0.834370152	0.634370152
RS3-3 VS RS3-5	3	1	1	0.2	0.2	0.880112	3	0.5	0.5	0.54005587	1.940055868	1.240055868
RS3-3 VS RS3-6	3	5	3	1	1	2.59002	5	0.5	0.5	1.79501003	3.795010032	2.795010032
RS3-3 VS RS3-7	0.3333	5	3	5	0.3333	2.236012	5	0.5	0.5	1.28465604	3.618006037	2.451331037
RS3-4 VS RS3-5	1	1	1	5	1	1.495349	5	0.5	0.5	1.24767439	3.247674391	2.247674391
RS3-4 VS RS3-6	1	5	3	5	1	2.942831	5	0.5	0.5	1.97141548	3.971415478	2.971415478
RS3-4 VS RS3-7	1	5	3	5	1	2.942831	5	0.5	0.5	1.97141548	3.971415478	2.971415478
RS3-5 VS RS3-6	1	5	3	5	1	2.942831	5	0.5	0.5	1.97141548	3.971415478	2.971415478
RS3-5 VS RS3-7	0.3333	5	3	5	0.3333	2.236012	5	0.5	0.5	1.28465604	3.618006037	2.451331037
RS3-6 VS RS3-7	0.3333	0.2	3	5	0.2	0.999975	5	0.5	0.5	0.5999875	2.9999875	1.7999875
RS2-2												
RS3-8 VS RS3-9	7	5	5	7	5	5.91608	7	0.5	0.5	5.45803989	6.458039892	5.958039892
RS3-8 VS RS3-10	1	1	0.2	0.2	0.2	0.447214	1	0.5	0.5	0.3236068	0.723606798	0.523606798
RS3-8 VS RS3-11	1	5	5	5	1	3.343702	5	0.5	0.5	2.17185076	4.171850762	3.171850762
RS3-8 VS RS3-12	1	5	5	5	1	3.343702	5	0.5	0.5	2.17185076	4.171850762	3.171850762
RS3-8 VS RS3-13	1	5	5	5	1	3.343702	5	0.5	0.5	2.17185076	4.171850762	3.171850762
RS3-9 VS RS3-10	1	1	0.2	0.1429	0.1429	0.411164	1	0.5	0.5	0.27703222	0.705582224	0.491307224
RS3-9 VS RS3-11	1	5	5	0.2	0.2	1.495349	5	0.5	0.5	0.84767439	3.247674391	2.047674391

RS3-9 VS RS3-12	1	5	1	0.2	0.2	1	5	0.5	0.5	0.6	3	1.8
RS3-9 VS RS3-13	1	5	1	1	1	1.495349	5	0.5	0.5	1.24767439	3.247674391	2.247674391
RS3-10 VS RS3-11	1	5	5	7	1	3.637136	7	0.5	0.5	2.31856788	5.318567881	3.818567881
RS3-10 VS RS3-12	1	5	5	7	1	3.637136	7	0.5	0.5	2.31856788	5.318567881	3.818567881
RS3-10 VS RS3-13	1	1	5	7	1	2.432299	7	0.5	0.5	1.71614964	4.71614964	3.21614964
RS3-11 VS RS3-12	1	5	0.3333	5	0.3333	1.699002	5	0.5	0.5	1.01615088	3.349500884	2.182825884
RS3-11 VS RS3-13	1	5	0.3333	5	0.3333	1.699002	5	0.5	0.5	1.01615088	3.349500884	2.182825884
RS3-12 VS RS3-13	1	0.2	1	1	0.2	0.66874	1	0.5	0.5	0.43437015	0.834370152	0.634370152
RS2-3												
RS3-14 VS RS3-15	0.2	0.2	0.3333	0.3333	0.2	0.258186	0.3333	0.5	0.5	0.22909299	0.29574299	0.26241799
RS3-14 VS RS3-16	3	3	1	5	1	2.59002	5	0.5	0.5	1.79501003	3.795010032	2.795010032
RS3-14 VS RS3-17	3	1	3	3	1	2.279507	3	0.5	0.5	1.63975353	2.639753528	2.139753528
RS3-15 VS RS3-16	5	5	3	5	3	4.400559	5	0.5	0.5	3.70027934	4.700279342	4.200279342
RS3-15 VS RS3-17	3	5	3	3	3	3.408658	5	0.5	0.5	3.20432905	4.20432905	3.70432905
RS3-16 VS RS3-17	0.3333	1	1	0.2	0.2	0.50812	1	0.5	0.5	0.35406002	0.754060022	0.554060022
RS3-1												
RS4-1 VS RS4-2	7	5	7	7	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
RS3-2												
RS4-3 VS RS4-4	7	5	7	7	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
RS3-3												
RS4-5 VS RS4-6	7	7	7	5	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
RS3-4												

RS4-7 VS RS4-8	7	5	7	7	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
RS3-5												
RS4-9 VS RS4-10	7	7	7	5	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
RS3-6												
RS4-11 VS RS4-12	7	5	7	7	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
RS3-7												
RS4-13 VS RS4-14	7	7	5	7	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
RS4-2												
RS5-1 VS RS5-2	7	7	7	5	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
SC performance measures	**Experts' responses**				**Fuzzy pair-wise comparison matrix**			**uncertainty level**		**aggregate pair-wise comparison matrix**		
Supply Chain Agility	**EXP.1**	**EXP.2**	**EXP.3**	**EXP.4**	**MIN (L)**	**GEOMEAN (M)**	**MAX (U)**	α	λ	L_{ij}^{α}	U_{ij}^{α}	**Aggregation**
AG												
AG1-1 VS AG1-2	0.1479	1	0.3333	0.2	0.1479	0.315107	1	0.5	0.5	0.23150362	0.657553616	0.444528616
AG1-1 VS AG1-3	0.1479	5	0.3333	5	0.1479	1.053625	5	0.5	0.5	0.60076227	3.026812266	1.813787266
AG1-2 VS AG1-3	0.1479	5	0.3333	7	0.1479	1.146088	7	0.5	0.5	0.64699389	4.073043891	2.360018891
AG1-1												
AG2-1 VS AG2-2	1	1	1	1	1	1	1	0.5	0.5	1	1	1
AG2-1 VS AG2-3	1	1	1	1	1	1	1	0.5	0.5	1	1	1
AG2-2 VS AG2-3	1	1	3	3	1	1.732051	3	0.5	0.5	1.3660254	2.366025404	1.866025404
AG1-2												
AG2-4 VS AG2-5	1	1	0.3333	1	0.3333	0.759817	1	0.5	0.5	0.54655834	0.879908345	0.713233345
AG2-4VS AG2-6	1	1	3	3	1	1.732051	3	0.5	0.5	1.3660254	2.366025404	1.866025404
AG2-5 VS AG2-6	1	1	3	3	1	1.732051	3	0.5	0.5	1.3660254	2.366025404	1.866025404

AG1-3												
AG2-7 VS AG2-8	0.1111	0.2	3	1	0.1111	0.50812	3	0.5	0.5	0.30961002	1.754060022	1.031835022
AG2-7 VS AG2-9	0.1111	0.2	3	7	0.1111	0.826496	7	0.5	0.5	0.46879808	3.913248077	2.191023077
AG2-8 VS AG2-9	1	0.2	0.3333	7	0.2	0.826496	7	0.5	0.5	0.51324808	3.913248077	2.213248077
SC performance measures	**Experts' responses**				**Fuzzy pair-wise comparison matrix**			**uncertainty level**		**aggregate pair-wise comparison matrix**		
Supply Chain Costs	**EXP.1**	**EXP.2**	**EXP.3**	**EXP.4**	**MIN (L)**	**GEOMEAN (M)**	**MAX (U)**	α	λ	L_{ij}^{α}	U_{ij}^{α}	**Aggregation**
CO												
CO1-1 VS CO1-2	0.1479	1	0.2	1	0.1479	0.414715	1	0.5	0.5	0.2813074	0.707357404	0.494332404
CO1-1												
CO2-1 VS CO2-2	7	5	7	7	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
CO2-1 VS CO2-3	5	7	5	5	5	5.438787	7	0.5	0.5	5.21939326	6.219393265	5.719393265
CO2-1 VS CO2-4	7	7	7	5	5	6.435259	7	0.5	0.5	5.7176295	6.717629503	6.217629503
CO2-2 VS CO2-3	0.2	0.2	0.3333	0.2	0.2	0.227238	0.3333	0.5	0.5	0.2136191	0.280269096	0.246944096
CO2-2 VS CO2-4	1	1	1	1	1	1	1	0.5	0.5	1	1	1
CO2-3 VS CO2-4	5	5	3	5	3	4.400559	5	0.5	0.5	3.70027934	4.700279342	4.200279342
CO2-5												
CO3-1 VS CO3-2	7	1	5	5	1	3.637136	7	0.5	0.5	2.31856788	5.318567881	3.818567881
CO3-1 VS CO3-3	3	1	5	0.1429	0.1429	1.209987	5	0.5	0.5	0.67644373	3.104993734	1.890718734
CO3-2 VS CO3-3	1	1	0.3333	0.2	0.2	0.50812	1	0.5	0.5	0.35406002	0.754060022	0.554060022

SC performance measures	Experts' responses				Fuzzy pair-wise comparison matrix			uncertainty level		aggregate pair-wise comparison matrix		
Supply Chain Asset Management	**EXP.1**	**EXP.2**	**EXP.3**	**EXP.4**	**MIN (L)**	**GEOMEAN (M)**	**MAX (U)**	α	λ	L_{ij}^{α}	U_{ij}^{α}	**Aggregation**
AM												
AM1-1 VS AM1-2	5	1	5	5	1	3.343702	5	0.5	0.5	2.17185076	4.171850762	3.171850762
AM1-1 VS AM1-3	1	1	5	5	1	2.236068	5	0.5	0.5	1.61803399	3.618033989	2.618033989
AM1-1 VS AM1-4	1	1	0.3333	5	0.3333	1.136191	5	0.5	0.5	0.73474548	3.06809548	1.90142048
AM1-2 VS AM1-3	0.2	1	0.3333	1	0.2	0.50812	1	0.5	0.5	0.35406002	0.754060022	0.554060022
AM1-2 VS AM1-4	0.2	1	0.3333	0.2	0.2	0.3398	1	0.5	0.5	0.26990018	0.669900177	0.469900177
AM1-3 VS AM1-4	1	1	0.3333	0.2	0.2	0.50812	1	0.5	0.5	0.35406002	0.754060022	0.554060022
AM1-1												
AM2-1 VS AM2-2	1	1	0.2	5	0.2	1	5	0.5	0.5	0.6	3	1.8
AM2-1 VS AM2-3	7	1	5	5	1	3.637136	7	0.5	0.5	2.31856788	5.318567881	3.818567881
AM2-2 VS AM2-3	5	1	3	5	1	2.942831	5	0.5	0.5	1.97141548	3.971415478	2.971415478
AM1-4												
AM2-4 VS AM2-5	1	1	1	0.1429	0.1429	0.614834	1	0.5	0.5	0.37886713	0.807417128	0.593142128
AM2-4 VS AM2-6	1	1	0.3333	0.1429	0.1429	0.467161	1	0.5	0.5	0.30503066	0.733580665	0.519305665
AM2-5 VS AM2-6	1	1	1	1	1	1	1	0.5	0.5	1	1	1
AM2-5												
AM3-1 VS AM3-2	0.1111	0.2	5	7	0.1111	0.939081	7	0.5	0.5	0.52509047	3.969540469	2.247315469

AM3-1													
AM4-1 VS AM4-2	0.2	1	1	0.1429	0.1429	0.411164	1	0.5	0.5	0.27703222	0.705582224	0.491307224
AM3-2													
AM4-3 VS AM4-4	0.1479	1	1	5	0.1479	0.927331	5	0.5	0.5	0.53761525	2.963665251	1.750640251

Appendix 7.2- The aggregate pair-wise comparison matrix

To aggregate the experts' responses illustrated in Appendix 7.1, aggregate pair-wise comparison matrixes for the pair-wise questionnaire's responses were established. Then, Eigen value and Eigenvector were calculated for each aggregate pair-wise comparison matrix at each level following the procedures illustrated in section 4.2. Consequently, the relative weights of the bottled water company's SC performance measures at different levels were determined by aggregating the weights throughout the hierarchy of the SC (see Appendix 7.3). Finally, Consistency Index (CI) and the Consistency Ratio (CR) were calculated for each aggregate pair-wise comparison matrix at each level in order to verify the consistency of the comparison matrix (see Appendix 7.4).

The measurement algorithm was carried out by using Microsoft Excel Spreadsheets and PopTools add-in *(version 3.2 (build 5))*.

PopTools is "*an add-in for PC versions of Microsoft Excel (version 97 and up) that helps with the analysis of matrix population models and simulation of stochastic processes. It was originally written to analyse ecological models, but has much broader application. It has been used for studies of population dynamics, financial modelling, risk analysis, and calculation of bootstrap and resampling statistics.*" (PopTools, 2011)[(1)].

(1) PopTools (2011), *PopTools - version 3.2 (build 5)*. [on line] Available at: <http://www.poptools.org>.

The aggregate pair-wise comparison matrixes of the experts' responses with Eigen value and Eigenvector calculation for each aggregate pair-wise comparison matrix are presented below:

RL	RL1-1	RL1-2
RL1-1	1	0.55406
RL1-2	1.804859	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	35.7%	1.4024293
-2.2335E-17	0	64.3%	0.77703001

RL1-1	RL2-1	RL2-2	RL2-3	RL2-4
RL2-1	1	2.483995	0.406871	2.618034
RL2-2	0.402577	1	0.209189	1.8
RL2-3	2.45778	4.780356	1	6.649852
RL2-4	0.381966	0.555556	0.150379	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
4.025979844	0	24.2%	1.03628633
0.002680896	0	11.8%	2.12306453
-0.01433037	0.3232117	56.0%	44.2%
-0.01433037	-0.323212	8.0%	313.0%

RL1-2	RL2-5	RL2-6	RL2-7	RL2-8	RL2-9	RL2-10
RL2-5	1	2.646593	0.597047	1.75064	1.679908	0.55406
RL2-6	0.377844	1	1	1.658037	3.600543	1
RL2-7	1.674911	1	1	1.658037	4.89337	3.408657
RL2-8	0.57122	0.603123	0.603123	1	3.171851	2.247674
RL2-9	0.595271	0.277736	0.204358	0.315273	1	0.425643
RL2-10	1.804859	1	0.293371	0.444904	2.349385	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
6.604625445	0	19.2%	0.99345814
0.005050857	0	17.2%	1.01704833
-0.06387056	1.9405425	27.4%	0.55121891
-0.06387056	-1.940542	15.9%	1.01178763
-0.24096759	0.3270949	5.9%	2.51287935
-0.24096759	-0.327095	14.4%	1.21152771

RL2-1	RL3-1	RL3-2
RL3-1	1	2.813288
RL3-2	0.355456	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	73.8%	0.67772796
-1.442E-17	0	26.2%	1.90664414

RL2-2	RL3-3	RL3-4
RL3-3	1	2.247674
RL3-4	0.444904	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	69.2%	0.72245215
2.08709E-17	0	30.8%	1.6238372

RL2-3	RL3-5	RL3-6	RL3-7
RL3-5	1	2.541519	3.322876
RL3-6	0.393466	1	3.242025
RL3-7	0.300944	0.308449	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.092335095	0	57.0%	0.58496858
-0.04616755	-0.532353	30.3%	1.09840023
-0.04616755	0.5323529	12.7%	2.63094538

RL2-4	RL3-8	RL3-9	RL3-10	RL3-11
RL3-8	1	0.424453	2.451275	2.247674
RL3-9	2.355974	1	3.366025	3.59501
RL3-10	0.407951	0.297086	1	1.868095
RL3-11	0.444904	0.278163	0.535305	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
4.079376066	0	26.2%	0.95618236
-0.00641928	-0.568251	48.5%	0.5094617
-0.00641928	0.5682511	14.6%	1.72462584
-0.0665375	0	10.7%	2.33893883

RL3-1	RL4-1	RL4-2	RL4-3
RL4-1	1	5	0.49711
RL4-2	0.2	1	0.157833
RL4-3	2.011628	6.335805	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.023779986	0	33.8%	0.98590953
-0.01188999	-0.267888	7.9%	4.22572993
-0.01188999	0.2678882	58.3%	0.57173481

RL3-2	RL4-4	RL4-5	RL4-6
RL4-4	1	2.618034	0.455258
RL4-5	0.381966	1	0.470819
RL4-6	2.196557	2.123959	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.111247606	0	32.2%	1.03611886
-0.0556238	-0.585683	17.1%	1.94623069
-0.0556238	0.5856832	50.7%	0.65744229

RL3-3	RL4-7	RL4-8	RL4-9
RL4-7	1	5.719393	0.566443
RL4-8	0.174844	1	0.15075
RL4-9	1.765403	6.633514	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.01964206	0	36.6%	0.91194605
-0.00982103	-0.243342	7.4%	4.53421785
-0.00982103	0.2433424	56.1%	0.59421283

RL3-5	RL4-10	RL4-11	RL4-12
RL4-10	1	3.818568	0.566443
RL4-11	0.261878	1	0.380242
RL4-12	1.765403	2.629902	1

RL3-6	RL4-13	RL4-14	RL4-15
RL4-13	1	3.97816	0.566443
RL4-14	0.251372	1	0.396465
RL4-15	1.765403	2.522291	1

RL3-7	RL4-16	RL4-17
RL4-16	1	0.476368
RL4-17	2.099219	1

RL3-8	RL4-18	RL4-19
RL4-18	1	0.597047
RL4-19	1.674911	1

RL3-9	RL4-20	RL4-21
RL4-20	1	0.455258
RL4-21	2.196557	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.099261505	0	37.8%	0.88278596
-0.04963075	-0.552426	13.5%	2.463132
-0.04963075	0.5524257	48.7%	0.68435243

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.11765121	0	38.3%	0.86950472
-0.05882561	-0.602773	13.6%	2.45872855
-0.05882561	0.6027727	48.1%	0.69290191

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	32.3%	1.54960944
4.7217E-17	0	67.7%	0.73818383

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	37.4%	1.33745551
-3.2526E-18	0	62.6%	0.79852332

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	31.3%	68.7%
-3.6754E-17	0	68.7%	31.3%

RL3-11	RL4-22	RL4-23
RL4-22	1	1
RL4-23	1	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	50.0%	1
0	0	50.0%	1

RL4-1	RL5-1	RL5-2
RL5-1	1	2.646593
RL5-2	0.377844	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	72.6%	0.68892214
2.39067E-17	0	27.4%	1.82329647

RL4-4	RL5-3	RL5-4
RL5-3	1	2.599074
RL5-4	0.384752	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	72.2%	0.69237619
-2.3419E-17	0	27.8%	1.79953714

RL4-7	RL5-5	RL5-6
RL5-5	1	1.593142
RL5-6	0.62769	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	61.4%	0.81384519
2.0383E-17	0	38.6%	1.29657106

RL4-10	RL5-7	RL5-8
RL5-7	1	2.12012
RL5-8	0.471671	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	67.9%	0.73583568
-2.2551E-17	0	32.1%	1.56006011

RL4-13	RL5-9	RL5-10
RL5-9	1	2.12012
RL5-10	0.471671	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	67.9%	0.73583568
-2.2551E-17	0	32.1%	1.56006011

RL4-16	RL5-11	RL5-12
RL5-11	1	2.12012
RL5-12	0.471671	1

RL4-18	RL5-13	RL5-14
RL5-13	1	0.491307
RL5-14	2.035386	1

RL4-20	RL5-15	RL5-16
RL5-15	1	0.593142
RL5-16	1.685937	1

RL4-22	RL5-17	RL5-18
RL5-17	1	1.190309
RL5-18	0.840118	1

RS	RS1-1	RS1-2
RS1-1	1	4.791288
RS1-2	0.208712	1

RS1-1	RS2-1	RS2-2	RS2-3
RS2-1	1	0.413215	0.494332
RS2-2	2.420045	1	0.63437
RS2-3	2.02293	1.576367	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	67.9%	32.1%
-2.2551E-17	0	32.1%	67.9%

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	32.9%	1.51769316
7.69784E-18	0	67.1%	0.74565361

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	37.2%	1.34296828
-1.6263E-17	0	62.8%	0.79657106

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	54.3%	0.9200591
7.96889E-18	0	45.7%	1.09515435

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	82.7%	0.60435608
-2.4178E-17	0	17.3%	2.89564392

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.044879608	0	18.3%	1.81935876
-0.0224398	-0.368984	35.9%	0.92881271
-0.0224398	0.3689844	45.8%	0.72795437

RS1-2	RS2-4	RS2-5
RS2-4	1	0.396465
RS2-5	2.522291	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	28.4%	1.76114542
-4.2392E-17	0	71.6%	0.69823249

RS2-1	RS3-1	RS3-2	RS3-3	RS3-4	RS3-5	RS3-6
RS3-1	1	0.63437	0.523607	0.44193	1.056286	1.134362
RS3-2	1.576367	1	0.523607	0.523607	1.023601	1.379146
RS3-3	1.90983	1.90983	1	0.63437	1.240056	2.79501
RS3-4	2.262803	1.90983	1.576367	1	2.247674	2.971415
RS3-5	0.946713	0.976943	0.806415	0.444904	1	2.971415
RS3-6	0.881553	0.725086	0.35778	0.33654	0.33654	1
RS3-7	0.976943	2.128112	0.407942	0.33654	0.407942	0.555559

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
7.369972782	0	10.1%	1.34695605
0.020527825	-0.107929	11.2%	1.37431718
0.020527825	0.1079295	19.4%	0.6698008
-0.00124429	1.5478192	25.7%	0.51412291
-0.00124429	-1.547819	15.2%	0.94919251
-0.20426992	0.5412998	8.7%	1.65773352
-0.20426992	-0.5413	9.6%	1.64911201

RS2-2	RS3-8	RS3-9	RS3-10	RS3-11	RS3-12	RS3-13
RS3-8	1	5.95804	0.523607	3.171851	3.171851	3.171851
RS3-9	0.16784	1	0.491307	2.047674	1.8	2.247674
RS3-10	1.90983	2.035386	1	3.818568	3.818568	3.21615
RS3-11	0.315273	0.488359	0.261878	1	2.182826	2.182826
RS3-12	0.315273	0.555556	0.261878	0.458122	1	0.63437
RS3-13	0.315273	0.444904	0.310931	0.458122	1.576367	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
6.417745511	0	31.3%	0.58057064
0.008011703	-1.466946	12.9%	1.39812477
0.008011703	1.4669456	31.9%	0.50172933
-0.05863944	0	10.1%	1.60954064
-0.18756474	-0.691927	6.4%	2.43242277
-0.18756474	0.6919273	7.4%	2.15108898

RS2-3	RS3-14	RS3-15	RS3-16	RS3-17
RS3-14	1	0.262418	2.79501	2.139754
RS3-15	3.810714	1	4.200279	3.704329
RS3-16	0.35778	0.238079	1	0.55406
RS3-17	0.467344	0.269954	1.804859	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
4.114590091	0	22.1%	1.14736459
-0.02642821	-0.683761	55.3%	0.46094086
-0.02642821	0.6837615	9.2%	2.70451351
-0.06173368	0	13.4%	1.81758007

RS3-1	RS4-1	RS4-2
RS4-1	1	6.21763
RS4-2	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

RS3-2	RS4-3	RS4-4
RS4-3	1	6.21763
RS4-4	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

RS3-3	RS4-5	RS4-6
RS4-5	1	6.21763
RS4-6	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

RS3-4	RS4-7	RS4-8
RS4-7	1	6.21763
RS4-8	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

RS3-5	RS4-9	RS4-10
RS4-9	1	6.21763
RS4-10	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

RS3-6	RS4-11	RS4-12
RS4-11	1	6.21763
RS4-12	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

RS3-7	RS4-13	RS4-14
RS4-13	1	6.21763
RS4-14	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

RS4-2	RS5-1	RS5-2
RS5-1	1	6.21763
RS5-2	0.160833	1

Eigenvalues		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	86.1%	0.5804165
2.57498E-17	0	13.9%	3.60881475

AG	AG1-1	AG1-2	AG1-3
AG1-1	1	0.444529	1.813787
AG1-2	2.249574	1	2.360019
AG1-3	0.551333	0.423725	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.033397363	0	28.3%	1.17867746
-0.01669868	-0.31785	53.0%	0.62885678
-0.01669868	0.31785	18.7%	1.78124754

AG1-1	AG2-1	AG2-2	AG2-3
AG2-1	1	1	1
AG2-2	1	1	1.866025
AG2-3	1	0.535898	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.043393773	0	32.9%	1.01446459
-0.02169689	-0.362758	40.5%	0.82400727
-0.02169689	0.3627583	26.7%	1.24894336

AG1-2	AG2-4	AG2-5	AG2-6
AG2-4	1	0.713233	1.866025
AG2-5	1.402066	1	1.866025
AG2-6	0.535898	0.535898	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.012703195	0	35.1%	0.95083132
-0.0063516	-0.195527	43.9%	0.75902819
-0.0063516	0.1955265	21.0%	1.58525176

AG1-3	AG2-7	AG2-8	AG2-9
AG2-7	1	1.031835	2.191023
AG2-8	0.969147	1	2.213248
AG2-9	0.456408	0.451825	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.000190732	0	41.1%	0.8109241
-9.5366E-05	-0.023921	40.4%	0.82526356
-9.5366E-05	0.0239212	18.5%	1.80146141

CO	CO1-1	CO1-2
CO1-1	1	0.494332
CO1-2	2.02293	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	33.1%	1.51146515
3.59955E-17	0	66.9%	0.7471662

CO1-1	CO2-1	CO2-2	CO2-3	CO2-4
CO2-1	1	6.21763	5.719393	6.21763
CO2-2	0.160833	1	0.246944	1
CO2-3	0.174844	4.0495	1	4.200279
CO2-4	0.160833	1	0.238079	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
4.230098085	0	64.7%	0.40542226
-3.1844E-20	0	7.0%	3.38132428
-0.11504904	0.9798475	21.3%	1.2288231
-0.11504904	-0.979848	7.0%	3.42512509

CO2-5	CO3-1	CO3-2	CO3-3
CO3-1	1	3.818568	1.890719
CO3-2	0.261878	1	0.55406
CO3-3	0.528899	1.804859	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.001404819	0	56.1%	0.59377439
-0.00070241	-0.06493	15.3%	2.18396251
-0.00070241	0.0649302	28.6%	1.16553466

AM	AM1-1	AM1-2	AM1-3	AM1-4
AM1-1	1	3.171851	2.618034	1.90142
AM1-2	0.315273	1	0.55406	0.4699
AM1-3	0.381966	1.804859	1	0.55406
AM1-4	0.525923	2.128112	1.804859	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
4.029629466	0	44.2%	0.56383358
-0.00294641	-0.345322	11.9%	2.10723797
-0.00294641	0.3453219	17.5%	1.43440008
-0.02373665	0	26.4%	0.9430262

AM1-1	AM2-1	AM2-2	AM2-3
AM2-1	1	1.8	3.818568
AM2-2	0.555556	1	2.971415
AM2-3	0.261878	0.33654	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.012628274	0	53.9%	0.61854981
-0.00631414	-0.194947	33.5%	0.99510459
-0.00631414	0.1949472	12.6%	2.64273522

AM1-4	AM2-4	AM2-5	AM2-6
AM2-4	1	0.593142	0.519306
AM2-5	1.685937	1	1
AM2-6	1.925648	1	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
3.001964034	0	21.7%	1.53483512
-0.00098202	-0.076779	38.3%	0.87091398
-0.00098202	0.0767789	40.0%	0.8331631

AM2-5	AM3-1	AM3-2
AM3-1	1	2.247315
AM3-2	0.444975	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	69.2%	0.72248768
-2.2768E-17	0	30.8%	1.62365773

AM3-1	AM4-1	AM4-2
AM4-1	1	0.491307
AM4-2	2.035386	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	32.9%	1.51769316
7.69784E-18	0	67.1%	0.74565361

AM3-2	AM4-3	AM4-4
AM4-3	1	1.75064
AM4-4	0.57122	1

Eigen values		Eigenvectors (R&L)	
Real	Imaginary	Age/stage struct	Reprod val
2	0	63.6%	0.78560979
4.67291E-17	0	36.4%	1.37532013

Appendix 7.3- The relative weights of the bottled water company's SC performance measures

Table A7.2: The relative weights of the bottled water company's SC performance measures at different levels

	Attribute code	Eigen vector (weight)
Supply Chain Reliability	**RL**	
Perfect Order Fulfilment	RL1-1	35.7%
Forecast Accuracy	RL1-2	64.3%
Perfect Order Fulfilment	RL1-1	
% of Orders Delivered in Full	RL2-1	24.2%
Delivery Performance to Customer Commit Date	RL2-2	11.8%
Perfect Condition	RL2-3	56.0%
Documentation Accuracy	RL2-4	8.0%
Forecast Accuracy	RL1-2	
Supply Chain Forecast Accuracy	RL2-5	19.2%
Source Forecast Accuracy	RL2-6	17.2%
Make Forecast Accuracy	RL2-7	27.4%
Deliver Forecast Accuracy	RL2-8	15.9%
Source Return Forecast Accuracy	RL2-9	5.9%
Deliver Return Forecast Accuracy	RL2-10	14.4%
% of Orders Delivered in Full	RL2-1	
Delivery Item Accuracy	RL3-1	73.8%
Delivery Quantity Accuracy	RL3-2	26.2%
Delivery Performance to Customer Commit Date	RL2-2	
Customer Commit Date Achievement Time Customer Receiving	RL3-3	69.2%
Delivery Location Accuracy	RL3-4	30.8%
Perfect Condition	RL2-3	
Orders Delivered Damage Free Conformance	RL3-5	57.0%
Orders Delivered Defect Free Conformance	RL3-6	30.3%
% Return	RL3-7	12.7%
Documentation Accuracy	RL2-4	
Shipping Documentation Accuracy	RL3-8	26.2%
Compliance Documentation Accuracy	RL3-9	48.5%
Other Required Documentation Accuracy	RL3-10	14.6%
Payment Documentation Accuracy	RL3-11	10.7%
Delivery Item Accuracy	RL3-1	
% Orders Processed With The Item Accuracy	RL4-1	33.8%
% Product Transferred without Item Errors	RL4-2	7.9%
% of Orders Delivered With The Item Accuracy	RL4-3	58.3%
Delivery Quantity Accuracy	RL3-2	
% Orders Processed With The Quantity Accuracy	RL4-4	32.2%
% Product Transferred without Quantity Errors	RL4-5	17.1%
% of Orders Delivered With The Quantity Accuracy	RL4-6	50.7%

Customer Commit Date Achievement Time Customer Receiving	RL3-3	
% of Orders Processed on time	RL4-7	36.6%
% Product Transferred On-Time to Demand Requirement	RL4-8	7.4%
% of Orders Delivered on time	RL4-9	56.1%
Orders Delivered Damage Free Conformance	RL3-5	
% of Orders Processed Damage Free	RL4-10	37.8%
% Product Transferred Damage Free to Demand Requirement	RL4-11	13.5%
% of Orders Delivered Damage Free	RL4-12	48.7%
Orders Delivered Defect Free Conformance	RL3-6	
% of Orders Processed Defect Free	RL4-13	38.3%
% Product Transferred Defect Free to Demand Requirement	RL4-14	13.6%
% of Orders Delivered Defect Free	RL4-15	48.1%
% Return	RL3-7	
% Source Return	RL4-16	32.3%
% Deliver Return	RL4-17	67.7%
Shipping Documentation Accuracy	RL3-8	
% Orders Received with Correct Shipping Documents	RL4-18	37.4%
% Orders Delivered with Correct Shipping Documents	RL4-19	62.6%
Compliance Documentation Accuracy	RL3-9	
% Orders Returned to Source with Correct Complaince Documents	RL4-20	31.3%
% Orders Returned with Correct Complaince Documents	RL4-21	68.7%
Payment Documentation Accuracy	RL3-11	
% Orders Received with Correct Payment Documents	RL4-22	50.0%
% Orders Delivered with Correct Payment Documents	RL4-23	50.0%
% Orders Processed With The Item Accuracy	RL4-1	
% Of DM Orders Processed With The Item Accuracy	RL5-1	72.6%
% Of INDM Orders Processed With The Item Accuracy	RL5-2	27.4%
% Orders Processed With The Quantity Accuracy	RL4-4	
% Of DM Orders Processed With The Quantity Accuracy	RL5-3	72.2%
% Of INDM Orders Processed With The Quantity Accuracy	RL5-4	27.8%
% of Orders Processed on time	RL4-7	
% of DM Orders Processed on time	RL5-5	61.4%
% of INDM Orders Processed on time	RL5-6	38.6%
% of Orders Processed Damage Free	RL4-10	
% of DM Orders Processed Damage Free	RL5-7	67.9%
% of INDM Orders Processed Damage Free	RL5-8	32.1%
% of Orders Processed Defect Free	RL4-13	
% of DM Orders Processed Defect Free	RL5-9	67.9%
% of INDM Orders Processed Defect Free	RL5-10	32.1%
% Source Return	RL4-16	

% DM Source Return	RL5-11	67.9%
% INDM Source Return	RL5-12	32.1%
% Orders Received with Correct Shipping Documents	RL4-18	
% DM Orders Received with Correct Shipping Documents	RL5-13	32.9%
% INDM Orders Received with Correct Shipping Documents	RL5-14	67.1%
% Orders Returned to Source with Correct Complaince Documents	RL4-20	
% DM Orders Returned to Source with Correct Complaince Documents	RL5-15	37.2%
% INDM Orders Returned to Source with Correct Complaince Documents	RL5-16	62.8%
% Orders Received with Correct Payment Documents	RL4-22	
% DM Orders Received with Correct Payment Documents	RL5-17	54.3%
% INDM Orders Received with Correct Payment Documents	RL5-18	45.7%
Supply Chain Responsiveness	**RS**	
Order Fulfilment Cycle Time	RS1-1	82.7%
Return Cycle Time	RS1-2	17.3%
Order Fulfilment Cycle Time	RS1-1	
Source Cycle Time	RS2-1	18.3%
Make Cycle Time	RS2-2	35.9%
Deliver Cycle Time	RS2-3	45.8%
Return Cycle Time	RS1-2	
Source Return Cycle Time	RS2-4	28.4%
Deliver Return Cycle Time	RS2-5	71.6%
Source Cycle Time	RS2-1	
Identify Sources of Supply Cycle Time	RS3-1	10.1%
Select Supplier and Negotiate Cycle Time	RS3-2	11.2%
Schedule Product Deliveries Cycle Time	RS3-3	19.4%
Receive Product Cycle Time	RS3-4	25.7%
Verify Product Cycle Time	RS3-5	15.2%
Transfer Product Cycle Time	RS3-6	8.7%
Authorize Supplier Payment Cycle Time	RS3-7	9.6%
Make Cycle Time	RS2-2	
Schedule Production Activities Cycle Time	RS3-8	31.3%
Issue Material Cycle Time	RS3-9	12.9%
Produce and Test Cycle Time	RS3-10	31.9%
Package Cycle Time	RS3-11	10.1%
Stage Finished Product Cycle Time	RS3-12	6.4%
Release Finished Product To Deliver Cycle Time	RS3-13	7.4%
Deliver Cycle Time	RS2-3	
Receive and validate order +Determining delivery date	RS3-14	22.1%
Receive product from warehouse +Pack product + Load vehicle	RS3-15	55.3%
Ship Product Cycle Time	RS3-16	9.2%
Receive & Verify Product Cycle Time	RS3-17	13.4%

Identify Sources of Supply Cycle Time	RS3-1	
Identify DM Sources of Supply Cycle Time	RS4-1	86.1%
Identify INDM Sources of Supply Cycle Time	RS4-2	13.9%
Select Supplier and Negotiate Cycle Time	RS3-2	
Select DM Supplier and Negotiate Cycle Time	RS4-3	86.1%
Select INDM Supplier and Negotiate Cycle Time	RS4-4	13.9%
Schedule Product Deliveries Cycle Time	RS3-3	
Schedule DM Product Deliveries Cycle Time	RS4-5	86.1%
Schedule INDM Product Deliveries Cycle Time	RS4-6	13.9%
Receive Product Cycle Time	RS3-4	
Receive DM Product Cycle Time	RS4-7	86.1%
Receive INDM Product Cycle Time	RS4-8	13.9%
Verify Product Cycle Time	RS3-5	
Verify DM Product Cycle Time	RS4-9	86.1%
Verify INDM Product Cycle Time	RS4-10	13.9%
Transfer Product Cycle Time	RS3-6	
Transfer DM Product Cycle Time	RS4-11	86.1%
Transfer INDM Product Cycle Time	RS4-12	13.9%
Authorize Supplier Payment Cycle Time	RS3-7	
Authorize DM Supplier Payment Cycle Time	RS4-13	86.1%
Authorize INDM Supplier Payment Cycle Time	RS4-14	13.9%
Identify INDM Sources of Supply Cycle Time	RS4-2	
Identify machines Sources of Supply Cycle Time	RS5-1	86.1%
Identify other INDM Sources of Supply Cycle Time	RS5-2	13.9%
Supply Chain Agility	**AG**	
Upside Supply Chain Flexibility	AG1-1	28.3%
Upside Supply Chain Adaptability	AG1-2	53.0%
Downside Supply Chain Adaptability	AG1-3	18.7%
Upside Supply Chain Flexibility	AG1-1	
Upside Source Flexibility	AG2-1	32.9%
Upside Make Flexibility	AG2-2	40.5%
Upside Deliver Flexibility	AG2-3	26.7%
Upside Supply Chain Adaptability	AG1-2	
Upside Source Adaptability	AG2-4	35.1%
Upside Make Adaptability	AG2-5	43.9%
Upside Deliver Adaptability	AG2-6	21.0%
Downside Supply Chain Adaptability	AG1-3	
Downside Source Adaptability	AG2-7	41.1%
Downside Make Adaptability	AG2-8	40.4%
Downside Deliver Adaptability	AG2-9	18.5%
Supply Chain Costs	**CO**	
Supply Chain Management Cost	CO1-1	33.1%
Cost of Goods Sold	CO1-2	66.9%
Supply Chain Management Cost	CO1-1	
Freight expense	CO2-1	64.7%
Direct marketing expense	CO2-2	7.0%
Direct sales expense	CO2-3	21.3%

Administrative expense	CO2-4	7.0%
Cost to Make	CO2-5	
M Cost	CO3-12	56.1%
L Cost	CO3-13	15.3%
Indirect Costs Related To Making Product	CO3-14	28.6%
Supply Chain Asset Management	**AM**	
Cash-to-Cash Cycle Time	AM1-1	44.2%
Return on Supply Chain Fixed Assets	AM1-2	11.9%
Return on Working Capital	AM1-3	17.5%
Capacity Utilization	AM1-4	26.4%
Cash-to-Cash Cycle Time	AM1-1	
Days Sales Outstanding	AM2-1	53.9%
Inventory Days of Supply	AM2-2	33.5%
Days Payable Outstanding	AM2-3	12.6%
Capacity Utilization	AM1-4	
Operating Rate	AM2-4	21.7%
Downtime	AM2-5	38.3%
% spoilage Material	AM2-6	40.0%
Downtime	AM2-5	
Scheduled Downtime	AM3-1	69.2%
Unscheduled Downtime	AM3-2	30.8%
Scheduled Downtime	AM3-1	
Scheduled Process Downtime	AM4-1	32.9%
Scheduled Equipment Downtime	AM4-2	67.1%
Unscheduled Downtime	AM3-2	
Unscheduled Process Downtime	AM4-3	63.6%
Unscheduled Equipment Downtime	AM4-4	36.4%

Appendix 7.4- The consistency test

Table A7.3: The Consistency Index (CI) and the Consistency Ratio (CR) for the aggregate pair-wise comparison matrixes

MATRIX CODE	EIGENVALUE	N	test the consistency		
			CI	RI	CR
RL	2	2			
RL1-1	4.025979844	4	0.00865995	0.9	0.00962216
RL1-2	6.604625445	6	0.12092509	1.24	0.09752023
RL2-1	2	2			
RL2-2	2	2			
RL2-3	3.092335095	3	0.04616755	0.58	0.07959922
RL2-4	4.079376066	4	0.02645869	0.9	0.02939854
RL3-1	3.023779986	3	0.01188999	0.58	0.02049999
RL3-2	3.111247606	3	0.0556238	0.58	0.09590311
RL3-3	3.01964206	3	0.00982103	0.58	0.01693281
RL3-5	3.099261505	3	0.04963075	0.58	0.08557026
RL3-6	3.11765121	3	0.05882561	0.58	0.10142346
RL3-7	2	2			
RL3-8	2	2			
RL3-9	2	2			
RL3-11	2	2			
RL4-1	2	2			
RL4-4	2	2			
RL4-7	2	2			
RL4-10	2	2			
RL4-13	2	2			
RL4-16	2	2			
RL4-18	2	2			
RL4-20	2	2			
RL4-22	2	2			
RS	2	2			
RS1-1	3.044879608	3	0.0224398	0.58	0.03868932
RS1-2	2	2			
RS2-1	7.369972782	7	0.06166213	1.32	0.04671374
RS2-2	6.417745511	6	0.0835491	1.24	0.06737831
RS2-3	4.114590091	4	0.0381967	0.9	0.04244077
RS3-1	2	2			
RS3-2	2	2			
RS3-3	2	2			
RS3-4	2	2			
RS3-5	2	2			
RS3-6	2	2			
RS3-7	2	2			
RS4-2	2	2			

AG	3.033397363	3	0.01669868	0.58	0.02879083
AG1-1	3.043393773	3	0.02169689	0.58	0.03740843
AG1-2	3.012703195	3	0.0063516	0.58	0.01095103
AG1-3	3.000190732	3	9.5366E-05	0.58	0.00016442
CO	2	2			
CO1-1	4.230098085	4	0.07669936	0.9	0.08522151
CO2-5	3.001404819	3	0.00070241	0.58	0.00121105
AM	4.029629466	4	0.00987649	0.9	0.01097388
AM1-1	3.012628274	3	0.00631414	0.58	0.01088644
AM1-4	3.001964034	3	0.00098202	0.58	0.00169313
AM2-5	2	2			
AM3-1	2	2			
AM3-2	2	2			

APPENDIX 8- The performance rating scale of the bottled water company's SC performance measures

Table A8.1: The performance rating scale of the bottled water company's SC performance measures

				Performance rating scale				
Performance Attribute Code	Performance Attribute Name	**MIN**	**MAX**	VP	P	G	VG	E
Supply Chain Reliability								
RL.5.1	% Of DM Orders Processed With The Item Accuracy	90	100	90	92.5	95	97.5	100
RL.5.2	% Of INDM Orders Processed With The Item Accuracy	90	100	90	92.5	95	97.5	100
RL.4.2	% Product Transferred without Item Errors	95	100	95	96.25	97.5	98.75	100
RL.4.3	% of Orders Delivered With The Item Accuracy	90	100	90	92.5	95	97.5	100
RL.5.3	% Of DM Orders Processed With The Quantity Accuracy	70	95	70	76.25	82.5	88.75	95
RL.5.4	% Of INDM Orders Processed With The Quantity Accuracy	90	100	90	92.5	95	97.5	100
RL.4.5	% Product Transferred without Quantity Errors	95	100	95	96.25	97.5	98.75	100
RL.4.6	% of Orders Delivered With The Quantity Accuracy	90	100	90	92.5	95	97.5	100
RL.5.5	% of DM Orders Processed on time	75	95	75	80	85	90	95
RL.5.6	% of INDM Orders Processed on time	70	95	70	76.25	82.5	88.75	95
RL.4.8	% Product Transferred On-Time to Demand Requirement	95	100	95	96.25	97.5	98.75	100
RL.4.9	% of Orders Delivered on time	90	100	90	92.5	95	97.5	100
RL.3.4	%Delivery Location Accuracy	90	100	90	92.5	95	97.5	100
RL.5.7	% of DM Orders Processed Damage Free	98	100	98	98.5	99	99.5	100
RL.5.8	% of INDM Orders Processed Damage Free	95	100	95	96.25	97.5	98.75	100
RL.4.11	% Product Transferred Damage Free to Demand Requirement	95	100	95	96.25	97.5	98.75	100
RL.4.12	% of Orders Delivered Damage Free	95	100	95	96.25	97.5	98.75	100
RL.5.9	% of DM Orders Processed Defect Free	80	95	80	83.75	87.5	91.25	95
RL.5.10	% of INDM Orders Processed Defect Free	75	100	75	81.25	87.5	93.75	100
RL.4.14	% Product Transferred Defect Free to Demand Requirement	95	100	95	96.25	97.5	98.75	100
RL.4.15	% of Orders Delivered Defect Free	90	100	90	92.5	95	97.5	100
RL.5.11	% DM Source Return	10	5	10	8.75	7.5	6.25	5
RL.5.12	% INDM Source Return	25	0	25	18.75	12.5	6.25	0
RL.4.17	% Deliver Return	20	3	20	15.75	11.5	7.25	3
RL.5.13	% DM Orders Received with Correct Shipping Documents	97	100	97	97.75	98.5	99.25	100
RL.5.14	% INDM Orders Received with Correct Shipping Documents	75	100	75	81.25	87.5	93.75	100
RL.4.19	% Orders Delivered with Correct Shipping Documents	97	100	97	97.75	98.5	99.25	100
RL.5.15	% DM Orders Returned to Source with Correct Compliance Documents	97	100	97	97.75	98.5	99.25	100

RL.5.16	% INDM Orders Returned to Source with Correct Compliance Documents	90	100	90	92.5	95	97.5	100
RL.4.21	% Orders Returned with Correct Compliance Documents	97	100	97	97.75	98.5	99.25	100
RL.3.10	Other Required Documentation Accuracy(NO of NCRs)	4	1	4	3.25	2.5	1.75	1
RL.5.17	% DM Orders Received with Correct Payment Documents	95	100	95	96.25	97.5	98.75	100
RL.5.18	% INDM Orders Received with Correct Payment Documents	90	100	90	92.5	95	97.5	100
RL.4.23	% Orders Delivered with Correct Payment Documents	95	100	95	96.25	97.5	98.75	100
RL.2.5	Supply Chain Forecast Accuracy (%)	0.6	0.8	0.6	0.65	0.7	0.75	0.8
RL.2.6	Source Forecast Accuracy (%)	0.7	1	0.7	0.775	0.85	0.925	1
RL.2.7	Make Forecast Accuracy (%)	0.7	1	0.7	0.775	0.85	0.925	1
RL.2.8	Deliver Forecast Accuracy (%)	0.7	1	0.7	0.775	0.85	0.925	1
RL.2.9	Source Return Forecast Accuracy (%)	0.7	1	0.7	0.775	0.85	0.925	1
RL.2.10	Deliver Return Forecast Accuracy(%)	0.6	0.8	0.6	0.65	0.7	0.75	0.8
Supply Chain Responsiveness								
RS.4.1	Identify DM Sources of Supply Cycle Time(days)	7	5	7	6.5	6	5.5	5
RS 5-1	Identify machines Sources of Supply Cycle Time(days)	120	30	120	97.5	75	52.5	30
RS 5-2	Identify other INDM Sources of Supply Cycle Time(days)	30	7	30	24.25	18.5	12.75	7
RS.4.3	Select DM Supplier and Negotiate Cycle Time(days)	30	14	30	26	22	18	14
RS.4.4	Select INDM Supplier and Negotiate Cycle Time(days)	30	7	30	24.25	18.5	12.75	7
RS.4.5	Schedule DM Product Deliveries Cycle Time(days)	2	1	2	1.75	1.5	1.25	1
RS.4.6	Schedule INDM Product Deliveries Cycle Time(days)	30	7	30	24.25	18.5	12.75	7
RS.4.7	Receive DM Product Cycle Time(days)	30	7	30	24.25	18.5	12.75	7
RS.4.8	Receive INDM Product Cycle Time(days)	60	7	60	46.75	33.5	20.25	7
RS.4.9	Verify DM Product Cycle Time(days)	1	0.5	1	0.875	0.75	0.625	0.5
RS.4.10	Verify INDM Product Cycle Time(days)	14	7	14	12.25	10.5	8.75	7
RS.4.11	Transfer DM Product Cycle Time(days)	1	0.5	1	0.875	0.75	0.625	0.5
RS.4.12	Transfer INDM Product Cycle Time(days)	14	7	14	12.25	10.5	8.75	7
RS.4.13	Authorize DM Supplier Payment Cycle Time(days)	30	60	30	37.5	45	52.5	60
RS.4.14	Authorize INDM Supplier Payment Cycle Time(days)	7	50	7	17.75	28.5	39.25	50
RS.3.8	Schedule Production Activities Cycle Time(days)	10	7	10	9.25	8.5	7.75	7
RS.3.9	Issue Material Cycle Time(hours)	0	0	0	0	0	0	0
RS.3.10	Produce and Test Cycle Time(hours)	10	8	10	9.5	9	8.5	8

RS.3.11	Package Cycle Time(hours)	0	0	0	0	0	0	0
RS.3.12	Stage Finished Product Cycle Time(hours)	0	0	0	0	0	0	0
RS.3.13	Release Finished Product To Deliver Cycle Time(hours)	0	0	0	0	0	0	0
RS.3.14	Receive and validate order +Determining delivery date (days)	48	24	48	42	36	30	24
RS.3.15	Receive product from warehouse +Pack product + Load vehicle (hours)	72	24	72	60	48	36	24
RS.3.16	Ship Product Cycle Time(days)	3	1	3	2.5	2	1.5	1
RS.3.17	Receive & Verify Product Cycle Time(hours)	0	0	0	0	0	0	0
RS.2.4	Source Return Cycle Time(days)	90	21	90	72.75	55.5	38.25	21
RS.2.5	Deliver Return Cycle Time(days)	7	1	7	5.5	4	2.5	1
Supply Chain Agility								
AG.2.1	Upside Source Flexibility(days)	15	2	15	11.75	8.5	5.25	2
AG.2.2	Upside Make Flexibility(days)	4	1	4	3.25	2.5	1.75	1
AG.2.3	Upside Deliver Flexibility(days)	3	1	3	2.5	2	1.5	1
AG.2.4	Upside Source Adaptability (Q %)	0.75	1	0.75	0.8125	0.875	0.9375	1
AG.2.5	Upside Make Adaptability (Q %)	0.3	0.7	0.3	0.4	0.5	0.6	0.7
AG.2.6	Upside Deliver Adaptability (Q %)	0.15	0.25	0.15	0.175	0.2	0.225	0.25
AG.2.7	Downside Source Adaptability (Q %)	0.3	0.6	0.3	0.375	0.45	0.525	0.6
AG.2.8	Downside Make Adaptability (Q %)	0.25	0.3	0.25	0.2625	0.275	0.2875	0.3
AG.2.9	Downside Deliver Adaptability (Q%)	0.25	0.3	0.25	0.2625	0.275	0.2875	0.3
Supply Chain Costs								
CO.2.1	Freight expense(%of total cost)	0.17	0.108	0.17	0.155	0.139	0.124	0.108
CO.2.2	Direct marketing expense(%of total cost)	0.08	0.036	0.08	0.069	0.058	0.047	0.036
CO.2.3	Direct sales expense(%of total cost)	0.2	0.153	0.2	0.188	0.177	0.165	0.153
CO.2.4	Administrative expense(%of total cost)	0.02	0.009	0.02	0.017	0.015	0.012	0.009
CO.3.1	M Cost(%of total cost)	0.75	0.54	0.75	0.698	0.645	0.593	0.54
CO.3.2	L Cost(%of total cost)	0.15	0.09	0.15	0.135	0.12	0.105	0.09
CO.3.3	Indirect Costs Related To Making Product(%of total cost)	0.25	0.135	0.25	0.22	0.193	0.164	0.135
Supply Chain Asset Management								
AM.2.1	Days Sales Outstanding	77	57	77	72	67	62	57
AM.2.2	Inventory Days of Supply	26	16	26	23.5	21	18.5	16
AM.2.3	Days Payable Outstanding	30	44	30	33.5	37	40.5	44
AM.1.2	Return on Supply Chain Fixed Assets %	0.1	0.135	0.1	0.109	0.118	0.126	0.135
AM.1.3	Return on Working Capital %	0.3	0.54	0.3	0.36	0.42	0.48	0.54
AM.2.4	Operating Rate	85	95	85	87.5	90	92.5	95
AM.4.1	% Scheduled Process Downtime	16	14	16	15.5	15	14.5	14
AM.4.2	Scheduled Equipment Downtime (days)	5	4	5	4.75	4.5	4.25	4

AM.4.3	% Unscheduled Process Downtime	25	18	25	23.25	21.5	19.75	18
AM.4.4	%Unscheduled Equipment Downtime	7	5	7	6.5	6	5.5	5
AM.2.6	% spoilage Material	3	1	3	2.5	2	1.5	1

APPENDIX 9- The SCM KPIs system - an overview

The SCM KPIs system - an overview

The SCM KPIs system is a SW application utilising the SCOR FAHP technique to evaluate, monitor and control SC operations' performance. It was designed by the researcher and further developed by *Tatweer For Information Technology*, a software development company.

Structured Query Language (SQL) database was used to develop the SW application system based upon four major stages namely; setting up the application in SQL, enabling the departments to enter daily SC operations data, aggregating SC operations annual performance and calculating the SC index.

The developed SW application provides continuous feedback on supply chain performance and helps to decide the necessary corrective actions through calculating two indexes: Supply Chain Index (SCI) and Supply Chain Financial Link Index (SCFLI). SCI reveals SC operations' performance, while SCFLI measures and evaluates the impact of supply chain operations' performance on enhancing the overall financial performance. Analysing the indexes offers opportunities for detailed evaluation of SC operations' performance through tracing SC processes that need improvement resulting in more control over the daily SC operations.

The SCM KPIs system consists of four main pages:

1. Home page
2. Management
3. Dashboard
4. About

Figure A9.1: The SCM KPIs system main pages

Home page includes links to:

- Departments data entry
- Processes details
- Performance measures details
- End nodes details

Figure A9.2: The SCM KPIs system - Home page

- **Departments data entry**, where the daily SC activities' details at different departments (Commercial, Engineering, Financial, Follow up, Planning, Production, and Quality) are entered.

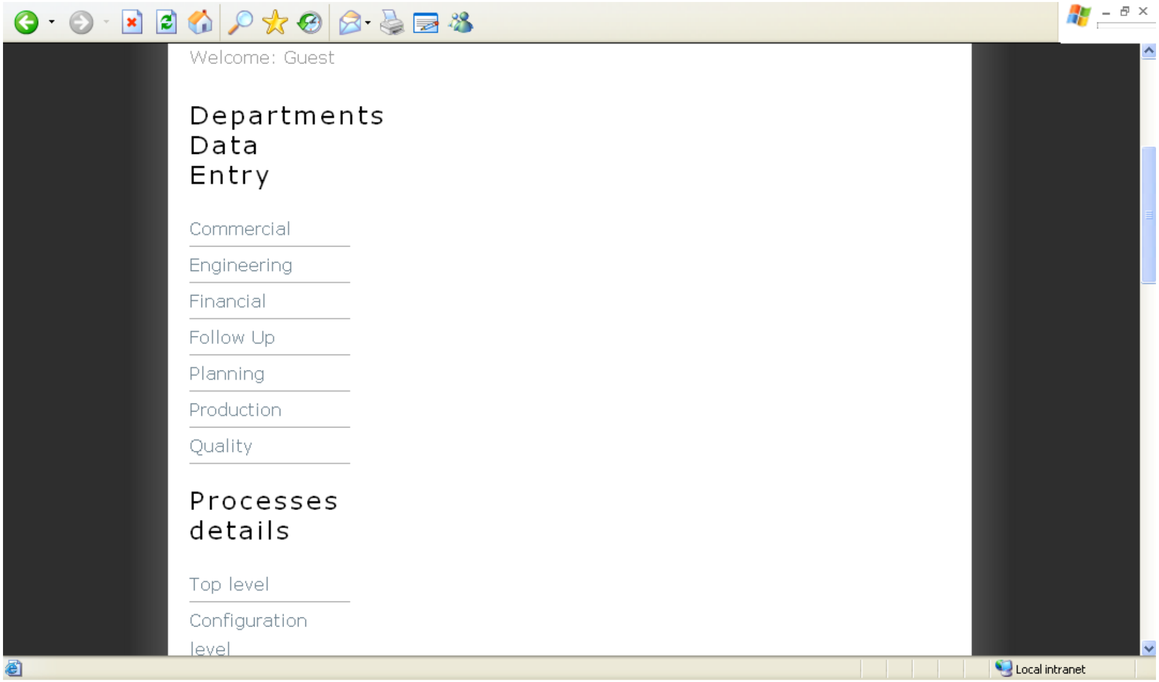


Figure A9.3: The SCM KPIs system - Departments data entry tab

- **Processes details**, where SC processes are mapped, from the top level till implementation levels, and their details are illustrated (i.e. process code, name, explanation, inputs, outputs, and responsible department for this process).

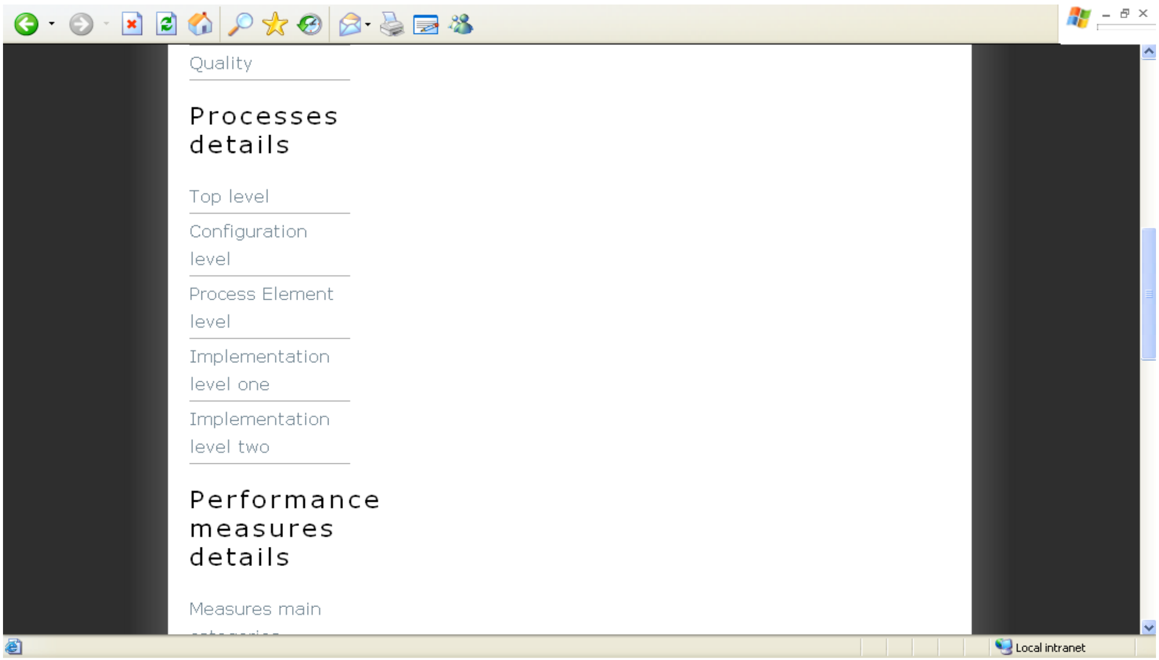


Figure A9.4: The SCM KPIs system - Processes details tab

- **Performance measures details**, where SC performance measures, from level 1 metrics till level 5 metrics, are described in details (performance attribute code, name, definition, calculation, and SC processes to which this performance attribute corresponds). Also a chart illustrating the hierarchy of SC performance measures with its different levels, starting from level 1 metrics till level 5 metrics, is presented.

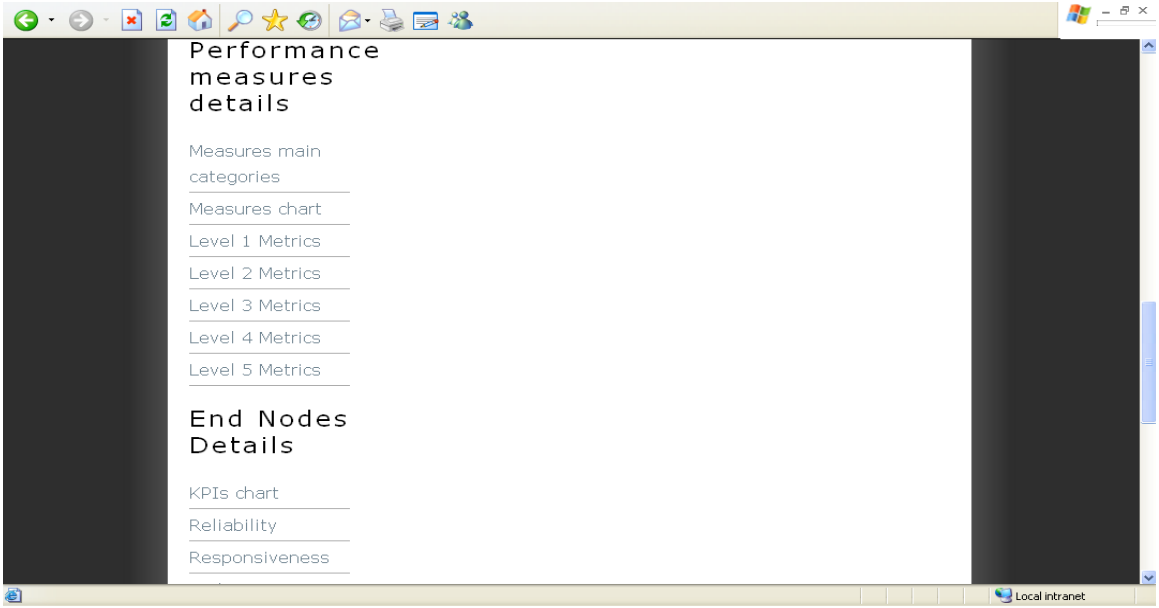


Figure A9.5: The SCM KPIs system - Performance measures tab

- **End nodes details**, where the details of the leaf nodes of SC performance measures are described.

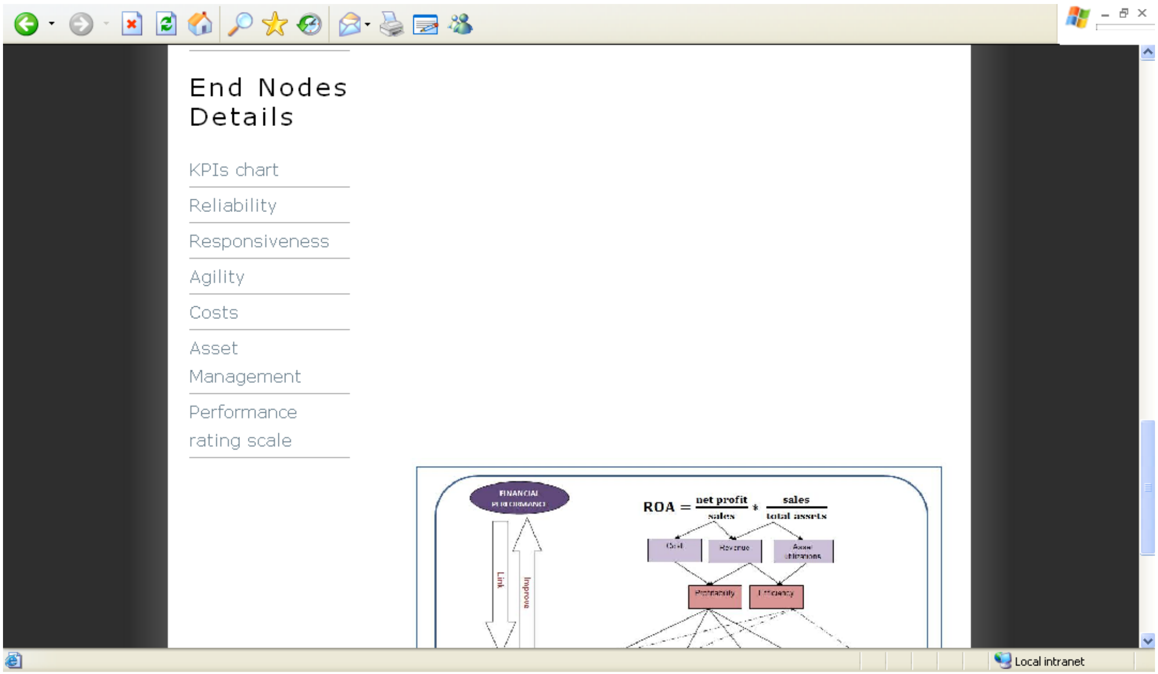


Figure A9.6: The SCM KPIs system - End nodes tab

Management includes links to:

- **SC annual performance**, where the annual performance of SC processes is illustrated and benchmarked to the performance rating scale in order to get the rate of each SC performance measure. After determining the performance rate of each measure, the weighted rate can be calculated by multiplying the importance weight of each measure by its performance rate.

- **SC performance rating scale**, this is the performance rating scale to which the annual performance of SC measures is benchmarked.

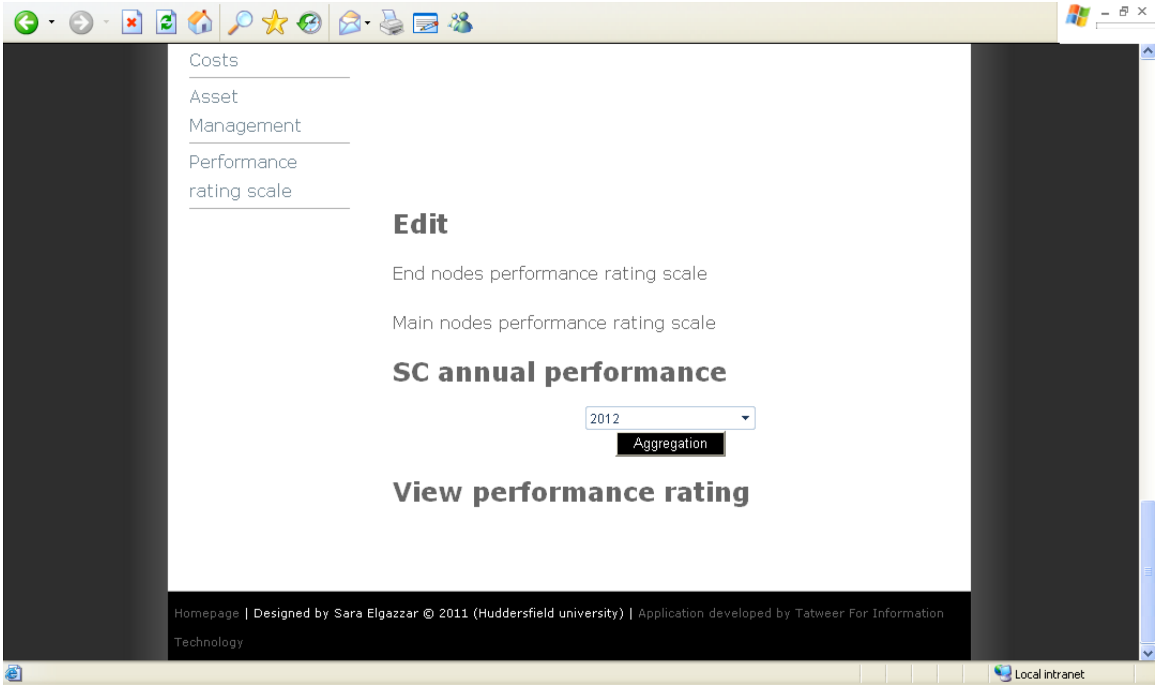
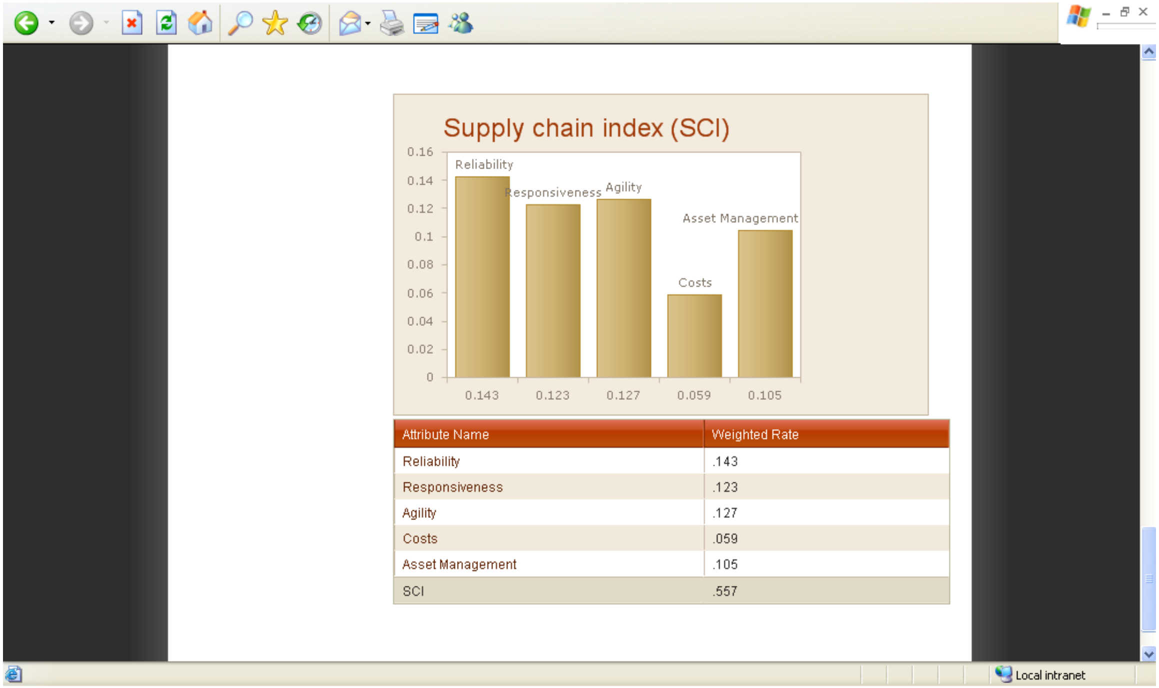


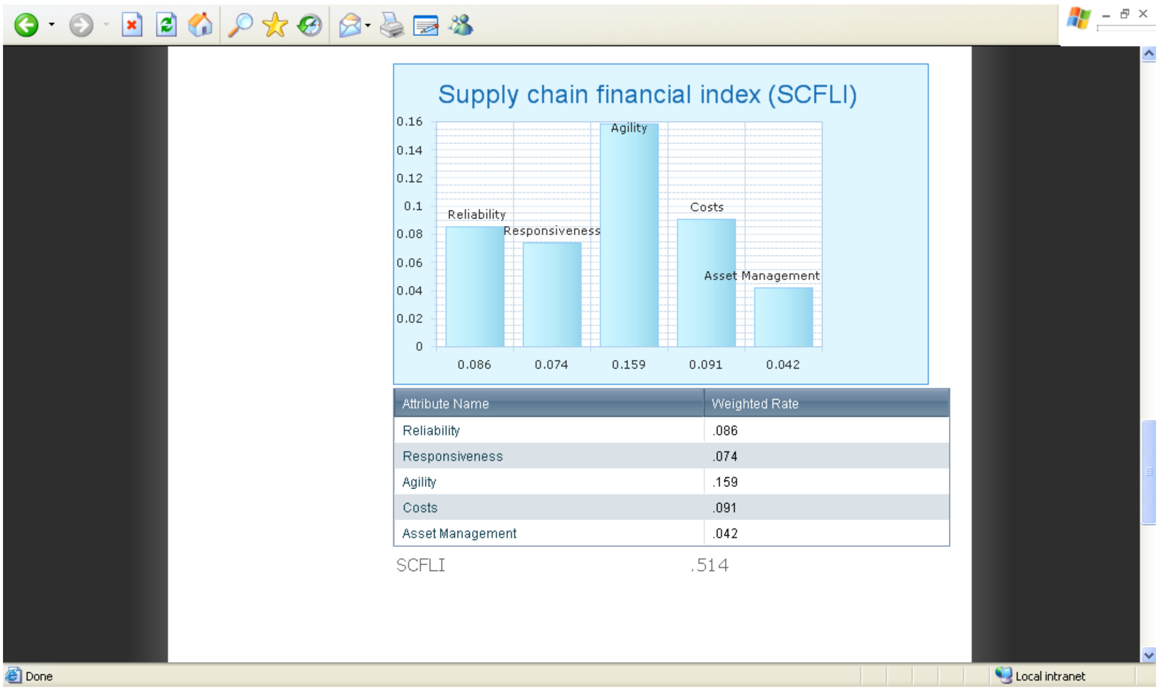
Figure A9.7: The SCM KPIs system - Management page

Dashboard:

This page includes charts summarising and analysing the annual SC performance.



Attribute Name	Weighted Rate
Reliability	.143
Responsiveness	.123
Agility	.127
Costs	.059
Asset Management	.105
SCI	.557



Attribute Name	Weighted Rate
Reliability	.086
Responsiveness	.074
Agility	.159
Costs	.091
Asset Management	.042

SCFLI .514

Figure A9.8: The SCM KPIs system - Dashboard

About:

This page provides information about:

- Programme idea

- The bottled water company

- Huddersfield University

- Tatweer For Information Technology, company by which this SW application was developed

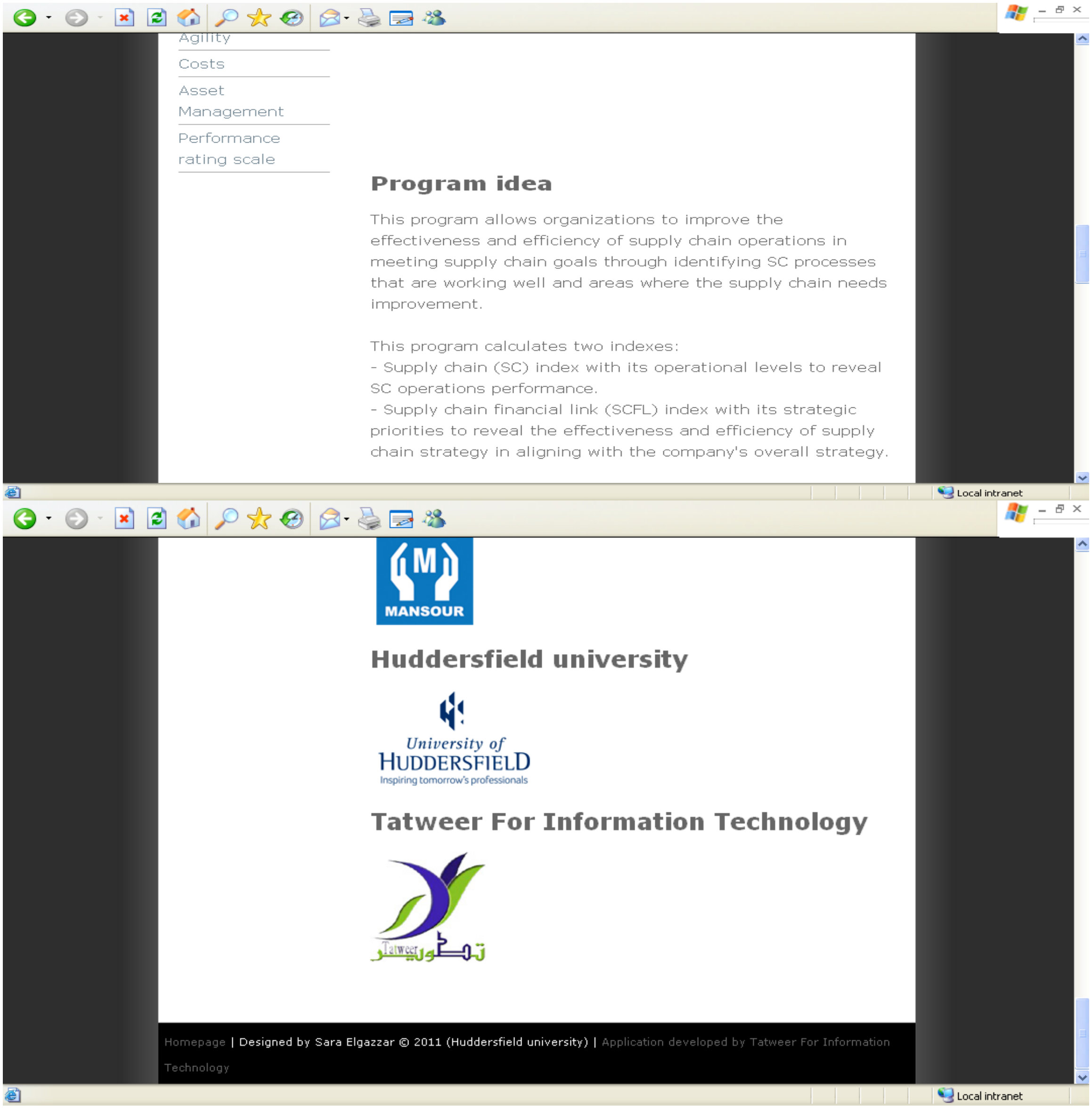


Figure A9.9: The SCM KPIs system - About page

APPENDIX 10- Samples of the bottled water company departments' data entry and results sheets for the year ended December 31st 2010

COMMERCIAL DEPARTMENT

Accuracy of month direct material orders

Home : Commercial Department : Accuracy of month DM orders

Accuracy of month DM orders

2010 ▾ January ▾

Insert New

Order #	Date	Item accuracy	Quantity accuracy	On time	Damage free	Defect free	Correct shipping documents	Correct payment documents	Is Returned ?	Returned	Returned with correct documents	User Comment
1/2010	1/1/2010	☑	☑	☑	☑	☐	☑	☑	☐	☐	☐	
1/2010 ALFA	1/1/2010	☑	☑	☑	☑	☐	☑	☑	☐	☐	☐	
1/2010 siwa	1/1/2010	☑	☑	☑	☑	☐	☑	☑	☐	☐	☐	
1/2010 polly pack	1/4/2010	☑	☐	☑	☑	☑	☑	☑	☐	☐	☐	
1/2010 Uni Pack	1/21/2010	☑	☐	☐	☑	☐	☑	☑	☐	☐	☐	
1/2010-1 H B Fuller	1/21/2010	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
1/2010 El Maraghi Pack	1/24/2010	☑	☐	☑	☑	☑	☑	☑	☐	☐	☐	
1/2010 Green Pack	1/24/2010	☑	☐	☐	☑	☑	☑	☑	☐	☐	☐	

Annual accuracy % of DM orders

Drag a column header and drop it here to group by that column

Month	Item accuracy	Quantity accuracy	On time	Damage free	Defect free	Correct shipping documents	correct payment documents	returned	returned with correct documents
1	100	58	75	100	58	100	100	0	0
10	94	65	65	100	94	100	100	12	100
11	100	43	43	100	71	100	100	0	0
12	100	50	92	100	58	100	100	0	0
2	100	50	67	100	50	100	100	0	0
3	100	43	86	100	100	100	100	29	100
4	100	40	90	100	90	100	100	0	0
5	100	60	80	93	93	100	100	7	100
6	100	55	100	100	100	100	91	0	0
7	100	46	85	100	85	100	100	0	0
8	91	43	83	100	87	100	100	0	0
9	100	33	56	100	89	100	100	11	100
	99	49	77	99	81	100	99	5	33

Accuracy of month source and source return forecast

Accuracy of month source and source return forecast

2010 | February

Insert New

Item #	Date	Item weight	Month source forecast					User Comment	Month source return forecast				
			Forecast	Actual	Forecast error	Absolute	Forecast accuracy		Forecast	Actual	Forecast error	Absolute	Forecast accuracy
1	2/28/2010	.03	1057311	860090	-0.007	0.007	0.032		10000		0.000	0.000	0.032
11	2/28/2010	.01	7	10	0.003	0.003	0.011				0.000	0.000	0.011
13	2/28/2010	.53	1	2	0.265	0.265	0.390				0.000	0.000	0.530
24	2/28/2010	.08	446	505	0.010	0.010	0.083		5		0.000	0.000	0.084
25	2/28/2010	.05	41668	43638	0.002	0.002	0.053		400		0.000	0.000	0.053
26	2/28/2010	.02	41668	50000	0.003	0.003	0.021		500		0.000	0.000	0.021
30	2/28/2010	.05	34842	36450	0.002	0.002	0.047		350		0.000	0.000	0.047
31	2/28/2010	.02	34842	12100	-0.030	0.030	0.016		500		0.000	0.000	0.016

Average cycle time of month DM orders

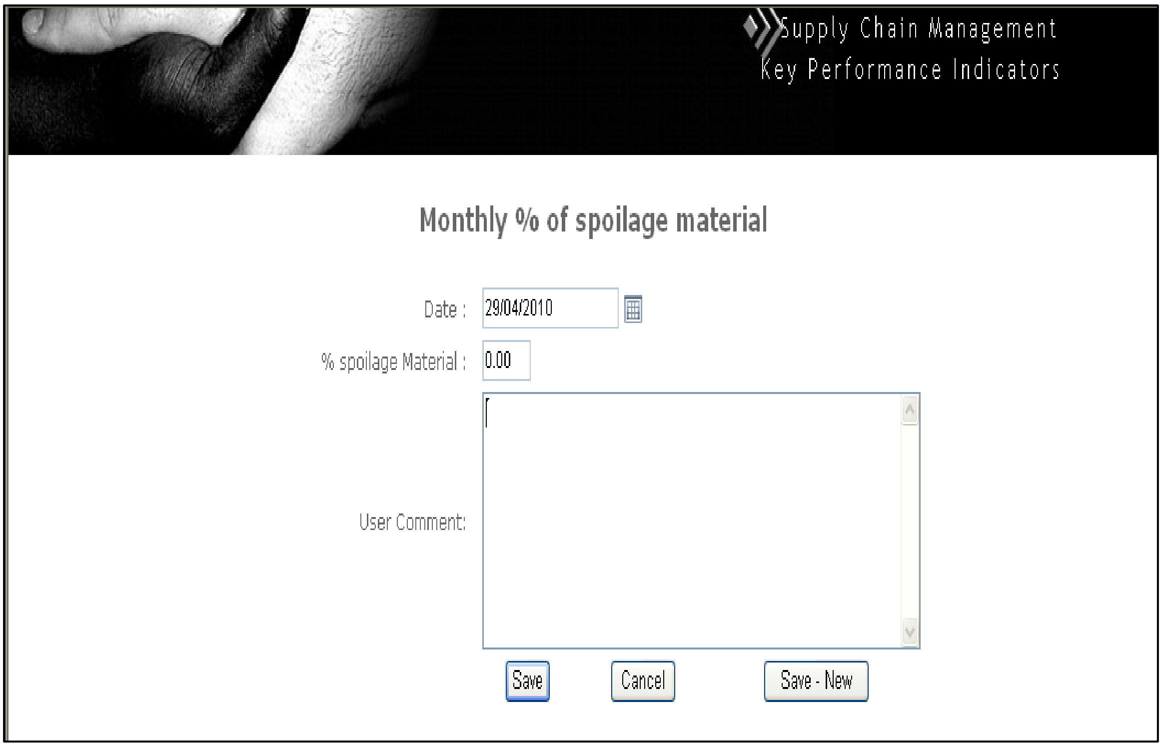
Average cycle time of month DM orders

2010 | March

Insert New

Order #	Date	Receive	Verify	Transfer to warehouse	Payment	New Item ?	Identify source	Select supplier	User Comment	Average source return cycle time	Return UC
1/2010-1taba group	3/1/2010	37	8	8	45		0	0			
1/2010-2taba group	3/1/2010	43	4	4	45		0	0			
1/2010-3taba group	3/1/2010	48	2	1	45		0	0			
1/2010-4taba group	3/1/2010	32	5	4	45		0	0			
1/2010-5taba group	3/1/2010	62	5	4	45		0	0			
1/2010-6taba group	3/1/2010	84	1	0	45		0	0			

Annual % of spoilage material



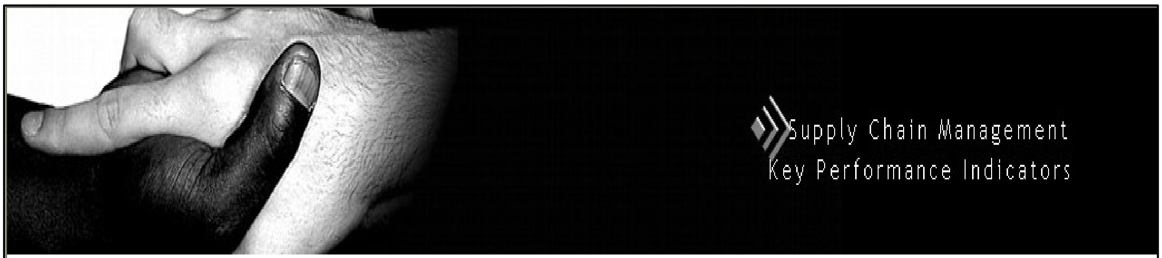
Annual % of spoilage material

2010

Insert New

Date	% spoilage Material	User Comment		
1/1/2010	.87			
2/1/2010	.61			
3/1/2010	.63			
4/1/2010	.7			
5/1/2010	.5			
6/1/2010	2.9			
7/1/2010	1.7			
8/1/2010	2			
9/1/2010	1.18			
10/1/2010	1.18			
11/1/2010	1.19			
12/1/2010	1.07			

Monthly schedule deliveries



Scheduled delivers (DAYS)

Date : 10/05/2010

Scheduled delivers (DAYS) : 0.00

User Comment:

Save | Cancel | Save - New

Monthly schedule deliveries

2010

Insert New

Date	Schedule delivers (DAYS)	User Comment		
1/1/2010	2			
2/1/2010	1			
3/1/2010	1			
4/1/2010	1			
5/1/2010	1			
6/1/2010	3			
7/1/2010	1			
8/1/2010	1			
9/1/2010	1			
10/1/2010	1			
11/1/2010	1			
12/1/2010	1			

Source agility

Home : Commercial Department : Source agility

Source agility

2010 ▾ August ▾

Insert New

Item #	Date	Upside flexibility	Upside adaptability	Is upside agility ?	Downside adaptability	User Comment		
24	8/30/2010	14	.19	☑				
14	8/31/2010			☐	.06			
15	8/31/2010	18	.06	☑				
40	8/31/2010			☐	.19			
5	8/31/2010	14	.14	☑				
79	8/31/2010			☐	.69			

ENGINEERING DEPARTMENT

Average %of month downtime

Home : Engineering Department : Average % of month down time

Average % of month down time

2010 | May

Insert New

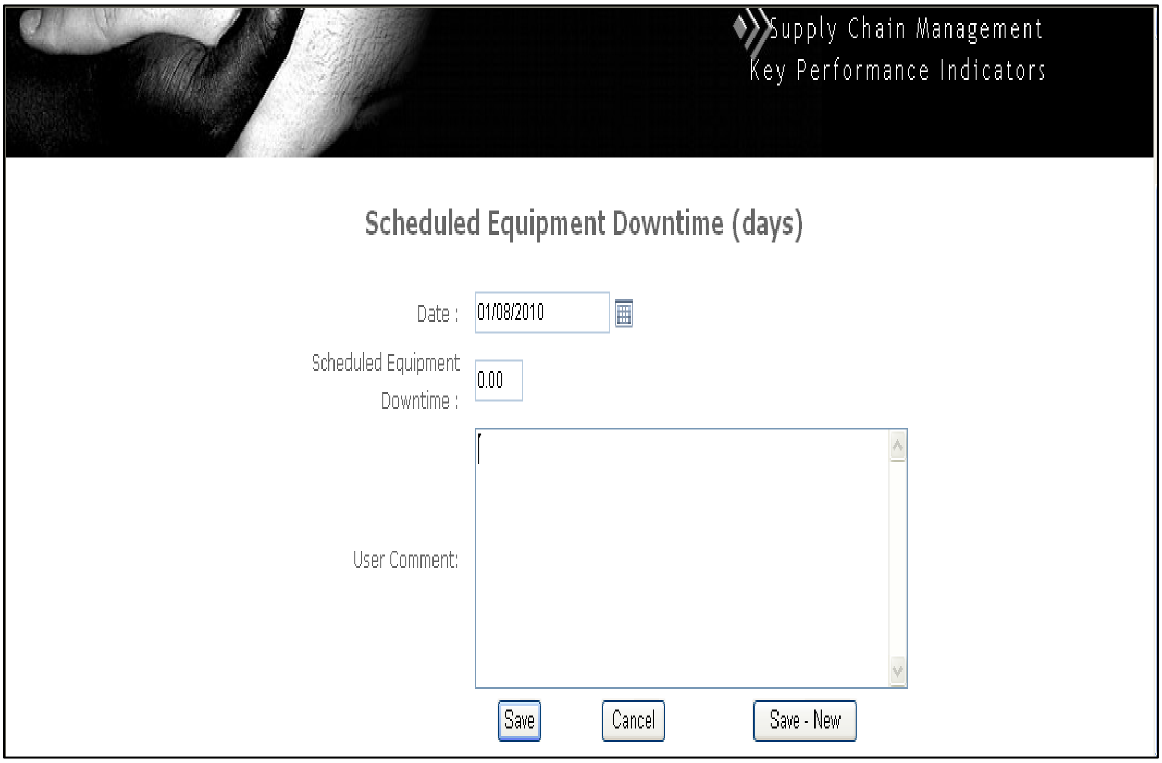
Line #	Date	Total operating hours	Scheduled Process Downtime	Unscheduled Process Downtime	Unscheduled Equipment Downtime	Actual operating hours	% Scheduled Process Downtime	% Unscheduled Process Downtime	% Unscheduled Equipment Downtime	User Comment
1	5/2/2010	16	2.33	1.17	.5	12	14.56	7.31	3.13	
3	5/2/2010	16	2	3		11	12.5	18.75		Unscheduled Process Downtime : تشغيل الخطين لنقص العمال
1	5/3/2010	16	2.25	1.17	1.33	11.25	14.06	7.31	8.31	

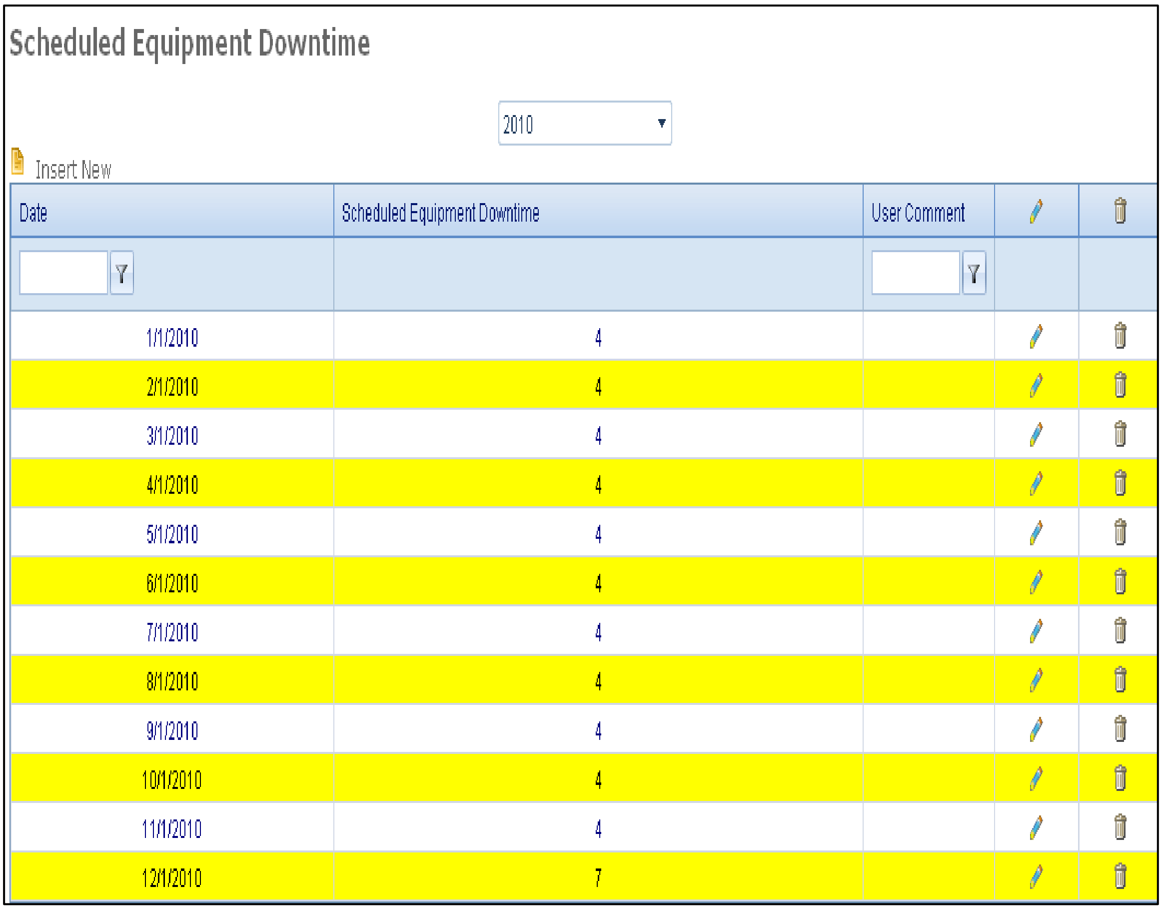
Average annual % of down time

Drag a column header and drop it here to group by that column

Month	Total operating hours	Scheduled Process Downtime	Unscheduled Process Downtime	Unscheduled Equipment Downtime	Actual operating hours	% Scheduled Process Downtime	% Unscheduled Process Downtime	% Unscheduled Equipment Downtime	Scheduled Equipment Downtime
1	652	47.58	273.09	39.75	291.58	304.32	1755.92	250.56	4
10	1140	180.95	317.04	81.91	560.1	1056.67	1767.02	514.46	4
11	1030	90.53	423.33	79.78	436.36	563.75	2582.69	461.65	4
12	1204	210.79	566.39	55.61	371.21	1321.73	3492.29	333.1	7
2	752	66.25	320.42	17.67	347.66	414.07	2002.63	110.44	4
3	832	52.41	343.9	30.9	404.79	327.57	2149.38	193.13	4
4	496	64.94	117.65	44.15	269.26	405.88	735.32	275.94	4
5	758	123.74	107.58	52.17	474.51	778.59	672.38	331.28	4
6	672	122.02	141.75	32.07	376.16	762.63	885.94	200.44	4
7	1036	219.73	239.56	28.57	548.14	1211.9	1275.06	161.84	4
8	815	120.12	117.32	42.32	535.24	837.3	774.46	300.62	4
9	899	190.29	156.98	55.8	495.93	1048.77	892.72	290.89	4

Scheduled equipment downtime





Scheduled Equipment Downtime

2010

Insert New

Date	Scheduled Equipment Downtime	User Comment		
1/1/2010	4			
2/1/2010	4			
3/1/2010	4			
4/1/2010	4			
5/1/2010	4			
6/1/2010	4			
7/1/2010	4			
8/1/2010	4			
9/1/2010	4			
10/1/2010	4			
11/1/2010	4			
12/1/2010	7			

FOLLOW UP DEPARTMENT

Annual accuracy % of INDM orders

Annual accuracy % of INDM orders

2010 ▾ August ▾

Insert New

Order #	Date	Item accuracy	Quantity accuracy	On time	Damage free	Defect free	Correct shipping documents	Correct payment documents	Is Returned ?	Returned	Returned with correct documents	User Comment
140	8/1/2010	☑	☑	☐	☑	☑	☑	☑	☐	☐	☐	LAB AND QUALITY
141	8/2/2010	☑	☑	☐	☑	☑	☑	☑	☐	☐	☐	ENGINEERING
143	8/2/2010	☑	☑	☐	☑	☑	☑	☑	☐	☐	☐	engineering
144	8/2/2010	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	ENGINEERING
146	8/3/2010	☑	☑	☐	☑	☑	☑	☑	☐	☐	☐	LAB AND QUALITY
142	8/4/2010	☑	☑	☐	☑	☑	☑	☑	☐	☐	☐	ENGINEERING
147	8/4/2010	☑	☑	☐	☑	☑	☑	☑	☐	☐	☐	PRODUCTION

Annual accuracy % of INDM orders

Drag a column header and drop it here to group by that column

Month	Item accuracy	Quantity accuracy	On time	Damage free	Defect free	Correct shipping documents	correct payment documents	returned	returned with correct documents
1	100	88	50	100	31	94	100	0	0
10	100	100	43	100	100	97	100	3	100
11	100	100	58	100	100	100	100	5	100
12	100	100	60	100	100	100	100	5	100
2	96	88	42	100	73	85	100	12	100
3	100	93	43	100	93	71	100	0	0
4	100	100	53	100	100	80	100	0	0
5	100	100	50	100	100	95	100	0	0
6	100	100	57	100	100	90	100	3	100
7	100	100	62	100	100	100	100	5	100
8	100	100	38	100	100	100	100	5	100
9	100	100	46	100	100	100	100	8	100

Accuracy of month delivered orders

Accuracy of month delivered orders

2010 ▾ August ▾

Insert New

Order #	Date	Item accuracy	Quantity accuracy	On time	Location accuracy	Damage free	Defect free	Correct shipping documents	Correct payment documents	Is Returned ?	Returned	Returned with correct documents	User Comment
S1/4	8/27/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
S2/4	8/27/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
A1/4	8/28/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
C1/4	8/28/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
C2/4	8/28/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
C3/4	8/28/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
C4/4	8/28/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
M1/4	8/28/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	
T1/4	8/28/2010	☑	☑	☑	☑	☑	☑	☑	☑	☐	☐	☐	

Accuracy of month deliver and deliver return forecast

Accuracy of deliver and deliver return forecast

2010 ▾ September ▾

Insert New

Product #	Date	Item weight	Deliver forecast					User Comment	Deliver return forecast				
			Forecast	Actual	Forecast error	Absolute	Forecast accuracy		Forecast	Actual	Forecast error	Absolute	Forecast accuracy
1	9/30/2010	.09	56527	44161	-0.025	0.025	0.088		442	7	-5.593	5.593	-0.413
2	9/30/2010	.25	142129	122193	-0.041	0.041	0.240		1222	409	-0.497	0.497	0.126
3	9/30/2010	.08	45128	38957	-0.013	0.013	0.079		390	7	-4.377	4.377	-0.270
4	9/30/2010	.21	121834	97354	-0.053	0.053	0.199		974	15	-13.426	13.426	-2.609
5	9/30/2010	.11	68750	51588	-0.037	0.037	0.106		516	18	-3.043	3.043	-0.225
6	9/30/2010	.17	121000	82862	-0.078	0.078	0.157		829	178	-0.622	0.622	0.064
7	9/30/2010	.09	57734	43432	-0.030	0.030	0.087		434	292	-0.044	0.044	0.086

Annual average cycle time of INDM orders

Annual average cycle time of INDM orders

2010

Insert New

Order #	Date	Schedule delivers	Receive	Verify	Transfer to warehouse	Payment	New Item ?	Identify source	Select supplier	User Comment
	1/14/2010	17	109	7	6	22		0	0	lab and quality
4	1/14/2010	7	7	4	3	26		0	0	engineering
	1/16/2010	59	3	7	6	0		0	0	lab and qulity
11	1/17/2010	0	66	8	7	40		0	0	engineering
4	1/18/2010	19	52	3	2	7		0	0	engineering
13	1/19/2010	7	2	1	1	23		0	0	engineering
6	1/19/2010	30	15	1	1	20		0	0	ENGINEERING
12	1/24/2010	40	17	4	4	12		0	0	ENGINEERING

Average cycle time of month delivered orders

Average cycle time of month deliver orders

2010 August

Insert New

Order #	Date	Receive and validate order+Determining delivery date	Receive product from warehouse+Pack product+Load vehicle	Ship product	Received and verified by customer	User Comment	Average deliver return cycle time	Return UC
S1/4	8/27/2010	24	4	72	0			
S2/4	8/27/2010	24	4	72	0			
A1/4	8/28/2010	24	4	24	0			
C1/4	8/28/2010	24	4	24	0			
C2/4	8/28/2010	24	4	24	0			
C3/4	8/28/2010	24	4	24	0			
C4/4	8/28/2010	24	4	24	0			
M1/4	8/28/2010	24	4	48	0			
T1/4	8/28/2010	24	4	24	0			
A2/4	8/29/2010	24	4	24	0			

Deliver agility

Deliver agility

2010

August

Insert New

Order #	Date	Upside flexibility	Upside adaptability	Is upside agility ?	Downside adaptability	User Comment		
1	8/31/2010			☐	.07			
2	8/31/2010			☐	.03			
3	8/31/2010	7	.04	☑				
4	8/31/2010			☐	.17			
5	8/31/2010			☐	.24			
6	8/31/2010	2	.47	☑				
7	8/31/2010	2	.14	☑				

PRODUCTION DEPARTMENT

Accuracy of month make forecast

Accuracy of month make forecast

2010 ▾ August ▾

Insert New

Product #	Date	Product weight	Month make forecast					User Comment
			Forecast	Actual	Forecast error	Absolute	Forecast accuracy	
1	8/31/2010	.08	78930	45311	-0.059	0.059	0.075	
2	8/31/2010	.22	101285	93804	-0.018	0.018	0.216	
3	8/31/2010	.08	40119	44362	0.008	0.008	0.079	
4	8/31/2010	.17	100837	86554	-0.028	0.028	0.165	
5	8/31/2010	.09	50000	48421	-0.003	0.003	0.090	
6	8/31/2010	.25	54610	124416	0.140	0.140	0.215	
7	8/31/2010	.11	63330	47275	-0.037	0.037	0.106	

Average make cycle time of month and average % ofmonth operating rate

Average make cycle time of month AND Average % of month operating rate

2010 ▾ August ▾

Insert New

Date	Production Line #	Shift #	Issue material	Production	Packaging	Enter warehouse	Release from warehouse	Actual output	Potential output	Operating rate	User Comment
8/1/2010	1	1	0	10	0	0	0	72372	96000	75.388	
8/1/2010	1	2	0	10	0	0	0	70032	96000	72.95	
8/2/2010	1	1	0	10	0	0	0	59904	96000	62.4	توقف لعدم توفر فوارغ ١٩ لتر
8/2/2010	1	2	0	10	0	0	0	43200	96000	45	
8/3/2010	1	1	0	10	0	0	0	75035	104000	72.149	
8/3/2010	1	2	0	10	0	0	0	90180	104000	86.712	
8/3/2010	3	1	0	10	0	0	0	3190	4800	66.458	
8/3/2010	3	2	0	10	0	0	0	5080	5600	90.714	
8/4/2010	1	1	0	10	0	0	0	97600	104000	93.846	
8/4/2010	1	2	0	10	0	0	0	96775	104000	93.053	

Make agility

Make agility

2010 ▾ July ▾

Insert New

Order #	Date	Upside flexibility	Upside adaptability	Is upside agility ?	Downside adaptability	User Comment
1	7/31/2010			☐	.42	
2	7/31/2010			☐	.23	
3	7/31/2010			☐	.62	
4	7/31/2010			☐	.91	
5	7/31/2010	1	.2	☑		
6	7/31/2010	2	.01	☑		
7	7/31/2010			☐	.25	

PLANNING DEPARTMENT

ISO documents accuracy

ISO documents accuracy

2010

Insert New

Date	Certificate	NO. of NCR	User Comment
1/1/2010	9001	1	
1/1/2010	22000	4	
1/1/2010	18001	1	

FINANCIAL DEPARTMENT

Yearly SC financial data

2010

Insert New

Month	Material cost	Labor cost	Indirect Costs Related To Making Product	Freight expense	Direct marketing expense	Direct sales expense	Administrative expense	Days Sales Outstanding	Inventory Days of Supply	Days Payable Outstanding	Return on Supply Chain Fixed Assets	Return on Working Capital	User Comment
12	.67	.14	.19	.17	.08	.21	.01	54	20	31	.06	-.01	

APPENDIX 11- The aggregated weighted rates of the bottled water company's SC performance measures for the year ended December 31st 2010

The aggregated weighted rates of the bottled water company's reliability performance measures for the year ended December 31st 2010:

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
RL									
Node : RL									
RL 1.1	Perfect Order Fulfillment	الدقة في إستيفاء الطلبيات	.2	1	.36		VG	.739	.266
RL 1.2	Forecast Accuracy	دقة التخطيط و التنبؤ	.2	1	.64		VG	.698	.447
RL 2.1	% of Orders Delivered in Full	نسبة الطلبيات التي تم إستيفائها كاملة(واردة أو صادرة بالكميات و النوعيات المحددة)	.2	1	.24		E	.844	.203
RL 2.2	Delivery Performance to Customer Commit Date	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد في الميعاد والمكان المتفق عليه	.2	1	.12		VG	.779	.093
RL 2.3	Perfect Condition	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد وفقا للجودة المتفق عليها	.2	1	.56		VG	.709	.397
RL 2.4	Documentation Accuracy	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد مرفق بها جميع المستندات المطلوبة صحيحة و كاملة	.2	1	.08		G	.577	.046
RL 2.5	Supply Chain Forecast Accuracy	دقة التخطيط و التنبؤ بسلسلة الإمداد ككل	.6	.8	.19	.564	VP	.2	.038
RL 2.6	Source Forecast Accuracy	دقة التخطيط و التنبؤ بأنشطة التوريد	.7	1	.17	1.555	E	1	.17
RL 2.7	Make Forecast Accuracy	دقة التخطيط و التنبؤ بمراحل التصنيع	.7	1	.27	.98	E	1	.27
RL 2.8	Deliver Forecast Accuracy	دقة التخطيط و التنبؤ بمراحل تسليم المنتج للعميل	.7	1	.16	.998	E	1	.16
RL 2.9	Source Return Forecast Accuracy	دقة التخطيط و التنبؤ بالمرتجعات للموردين	.7	1	.06	2.09	E	1	.06
RL 2.10	Deliver Return Forecast Accuracy	دقة التخطيط و التنبؤ للمرتجعات من العملاء	.6	.8	.15	.304	VP	.2	.03
RL 3.1	Delivery Item Accuracy	نسبة الطلبيات (واردة أو صادرة) التي تم إستيفائها كاملة من حيث النوعيات المحددة	.2	1	.74		E	.92	.681
RL 3.2	Delivery Quantity Accuracy	نسبة الطلبيات (واردة أو صادرة) التي تم إستيفائها كاملة من حيث الكميات المحددة	.2	1	.26		VG	.628	.163
RL 3.3	Customer Commit Date Achievement Time Customer Receiving	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد في الميعادالمتفق عليه	.2	1	.69		VG	.679	.469
RL 3.4	Delivery Location Accuracy	نسبة الطلبيات التي تم تسليمها للعملاء في المكان المتفق عليه	90	100	.31	99.847	E	1	.31
RL 3.5	Orders Delivered Damage Free Conformance	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد خالية من أي توالف	.2	1	.57		E	.818	.466
RL 3.6	Orders Delivered Defect Free Conformance	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد خالية من أي عيوب	.2	1	.3		VG	.681	.204
RL 3.7	% Return	نسبة المرتجعات للموردين أومن العملاء	.2	1	.13		P	.3	.039
RL 3.8	Shipping Documentation Accuracy	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد مرفق معها جميع مستندات الشحن المطلوبة صحيحة و كاملة	.2	1	.26		E	.95	.247
RL 3.9	Compliance Documentation Accuracy	نسبة المرتجعات التي تم إرسالها للمورد أو تلقيها من العملاء مرفق بها تقارير شكاوى واضحة و مستوفاة	.2	1	.48		P	.271	.13
RL 3.10	Other Required Documentation Accuracy	نسبة الدقة بمستندات الجودة (ISO documents)	4	1	.15	2	G	.6	.09

RL 3.11	Payment Documentation Accuracy	نسبة الطلبيات التي تم تسليمها للعملاء أوإستلامها من المورد مرفق معها جميع فواتير الدفع المطلوبة صحيحة و كاملة	.2	1	.11		E	1	.11
RL 4.1	% Orders Processed With The Item Accuracy	نسبة الطلبيات الواردة التي تم إستيفائها كاملة من حيث النوعيات المحددة	.2	1	.34		E	1	.34
RL 4.2	% Product Transferred without Item Errors	نسبة أوامر صرف مستلزمات الإنتاج التي تم إستيفائها كاملة من حيث النوعيات المحددة	95	100	.08		-		
RL 4.3	% of Orders Delivered With The Item Accuracy	نسبة الطلبيات الصادرة التي تم إستيفائها كاملة من حيث النوعيات المحددة	90	100	.58	99.847	E	1	.58
RL 4.4	% Orders Processed With The Quantity Accuracy	نسبة الطلبيات الواردة التي تم إستيفائها كاملة من حيث الكميات المحددة	.2	1	.32		P	.368	.118
RL 4.5	% Product Transferred without Quantity Errors	نسبة أوامر صرف مستلزمات الإنتاج التي تم إستيفائها كاملة من حيث الكميات المحددة	95	100	.17		-		
RL 4.6	% of Orders Delivered With The Quantity Accuracy	نسبة الطلبيات الصادرة التي تم إستيفائها كاملة من حيث الكميات المحددة	90	100	.51	99.847	E	1	.51
RL 4.7	% of Orders Processed on time	نسبة الطلبيات التي تم إستلامها من المورد في الميعادالمتفق عليه	.2	1	.37		P	.322	.119
RL 4.8	% Product Transferred On-Time to Demand Requirement	نسبة أوامر صرف مستلزمات الإنتاج التي تم صرفها في الميعادالمحدد	95	100	.07		-		
RL 4.9	% of Orders Delivered on time	نسبة الطلبيات التي تم تسليمها للعملاء في الميعادالمتفق عليه	90	100	.56	99.847	E	1	.56
RL 4.10	% of Orders Processed Damage Free	نسبة الطلبيات التي تم إستلامها من المورد خالية من أي توالف	.2	1	.38		E	.864	.328
RL 4.11	% Product Transferred Damage Free to Demand Requirement	نسبة أوامر صرف مستلزمات الإنتاج التي تم صرفها خالية من أي توالف	95	100	.13		-		
RL 4.12	% of Orders Delivered Damage Free	نسبة الطلبيات التي تم تسليمها للعملاء خالية من أي توالف	95	100	.49	99.847	E	1	.49
RL 4.13	% of Orders Processed Defect Free	نسبة الطلبيات التي تم إستلامها من المورد خالية من أي عيوب	.2	1	.38		G	.528	.201
RL 4.14	% Product Transferred Defect Free to Demand Requirement	نسبة أوامر صرف مستلزمات الإنتاج التي تم صرفها خالية من أي عيوب	95	100	.14		-		
RL 4.15	% of Orders Delivered Defect Free	نسبة الطلبيات التي تم تسليمها للعملاء خالية من أي عيوب	90	100	.48	99.847	E	1	.48
RL 4.16	% Source Return	نسبة المرتجعات للموردين	.2	1	.32		E	.936	.3
RL 4.17	% Deliver Return	نسبة المرتجعات من العملاء	20	3	.68		-		
RL 4.18	% Orders Received with Correct Shipping Documents	نسبة الطلبيات التي تم إستلامها من المورد مرفق معها جميع مستندات الشحن المطلوبة صحيحة و كاملة	.2	1	.37		E	.866	.32
RL 4.19	% Orders Delivered with Correct Shipping Documents	نسبة الطلبيات التي تم تسليمها للعملاء مرفق معها جميع مستندات الشحن المطلوبة صحيحة و كاملة	97	100	.63	99.847	E	1	.63
RL 4.20	% Orders Returned to Source with Correct Complaince Documents	نسبة المرتجعات التي تم إرسالها للمورد مرفق بها تقارير شكاوى واضحة و مستوفاة	.2	1	.31		E	.874	.271
RL 4.21	% Orders Returned with Correct Complaince Documents	نسبة المرتجعات التي تم تلقيها من العملاء مرفق بها تقارير شكاوى واضحة و مستوفاة	97	100	.69		-		
RL 4.22	% Orders Received with Correct Payment Documents	نسبة الطلبيات التي تم إستلامها من المورد مرفق معها جميع فواتير الدفع المطلوبة صحيحة و كاملة	.2	1	.5		E	1	.5

RL 4.23	% Orders Delivered with Correct Payment Documents	نسبة الطلبيات التي تم تسليمها للعملاء مرفق معها جميع فواتير الدفع المطلوبة صحيحة و كاملة	95	100	.5	99.847	E	1	.5
RL 5.1	% Of DM Orders Processed With The Item Accuracy	نسبة طلبيات مستلزمات الإنتاج المباشرة الواردة التي تم إستيفائها كاملة من حيث النوعيات المحددة	90	100	.73	98.785	E	1	.73
RL 5.2	% Of INDM Orders Processed With The Item Accuracy	نسبة طلبيات مستلزمات الإنتاج الغير المباشرة الواردة التي تم إستيفائها كاملة من حيث النوعيات المحددة	90	100	.27	99.264	E	1	.27
RL 5.3	% Of DM Orders Processed With The Quantity Accuracy	نسبة طلبيات مستلزمات الإنتاج المباشرة الواردة التي تم إستيفائها كاملة من حيث الكميات المحددة	70	95	.72	48.855	VP	.2	.144
RL 5.4	% Of INDM Orders Processed With The Quantity Accuracy	نسبة طلبيات مستلزمات الإنتاج الغير المباشرة الواردة التي تم إستيفائها كاملة من حيث الكميات المحددة	90	100	.28	97.236	VG	.8	.224
RL 5.5	% of DM Orders Processed on time	نسبة طلبيات مستلزمات الإنتاج المباشرة التي تم إستلامها من المورد في الميعاد المتفق عليه	75	95	.61	76.616	P	.4	.244
RL 5.6	% of INDM Orders Processed on time	نسبة طلبيات مستلزمات الإنتاج الغير المباشرة التي تم إستلامها من المورد في الميعاد المتفق عليه	70	95	.39	50.25	VP	.2	.078
RL 5.7	% of DM Orders Processed Damage Free	نسبة طلبيات مستلزمات الإنتاج المباشرة التي تم إستلامها من المورد خالية من أي توالف	98	100	.68	99.444	VG	.8	.544
RL 5.8	% of INDM Orders Processed Damage Free	نسبة طلبيات مستلزمات الإنتاج الغير المباشرة التي تم إستلامها من المورد خالية من أي توالف	95	100	.32	100	E	1	.32
RL 5.9	% of DM Orders Processed Defect Free	نسبة طلبيات مستلزمات الإنتاج المباشرة التي تم إستلامها من المورد خالية من أي عيوب	80	95	.68	81.334	P	.4	.272
RL 5.10	% of INDM Orders Processed Defect Free	نسبة طلبيات مستلزمات الإنتاج الغير المباشرة التي تم إستلامها من المورد خالية من أي عيوب	75	100	.32	92.537	VG	.8	.256
RL 5.11	% DM Source Return	نسبة المرتجعات للموردين من طلبيات مستلزمات الإنتاج المباشرة	10	5	.68	4.843	E	1	.68
RL 5.12	% INDM Source Return	نسبة المرتجعات للموردين من طلبيات مستلزمات الإنتاج الغير المباشرة	25		.32	3.659	VG	.8	.256
RL 5.13	% DM Orders Received with Correct Shipping Documents	نسبة طلبيات مستلزمات الإنتاج المباشرة التي تم إستلامها من المورد مرفق معها جميع مستندات الشحن المطلوبة صحيحة و كاملة	97	100	.33	100	E	1	.33
RL 5.14	% INDM Orders Received with Correct Shipping Documents	نسبة طلبيات مستلزمات الإنتاج الغير المباشرة التي تم إستلامها من المورد مرفق معها جميع مستندات الشحن المطلوبة صحيحة و كاملة	75	100	.67	92.127	VG	.8	.536
RL 5.15	% DM Orders Returned to Source with Correct Complaince Documents	نسبة المرتجعات من طلبيات مستلزمات الإنتاج المباشرة التي تم إرسالها للمورد مرفق بها تقارير شكاوي واضحة و مستوفاة	97	100	.37	100	E	1	.37
RL 5.16	% INDM Orders Returned to Source with Correct Complaince Documents	نسبة المرتجعات من طلبيات مستلزمات الإنتاج الغير المباشرة التي تم إرسالها للمورد مرفق بها تقارير شكاوي واضحة و مستوفاة	90	100	.63	96.875	VG	.8	.504
RL 5.17	% DM Orders Received with Correct Payment Documents	نسبة طلبيات مستلزمات الإنتاج المباشرة التي تم إستلامها من المورد مرفق معها جميع فواتير الدفع المطلوبة صحيحة و كاملة	95	100	.54	99.242	E	1	.54
RL 5.18	% INDM Orders Received with Correct Payment Documents	نسبة طلبيات مستلزمات الإنتاج الغير المباشرة التي تم إستلامها من المورد مرفق معها جميع فواتير الدفع المطلوبة صحيحة و كاملة	90	100	.46	100	E	1	.46

The aggregated weighted rates of the bottled water company's responsiveness performance measures for the year ended December 31st 2010:

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
RS									
Node : RS									
RS 1.1	Order Fulfillment Cycle Time	الدورة الزمنية اللازمة لإستيفاء الطلبيات	.2	1	.83		VG	.739	.613
RS 1.2	Return Cycle Time	(الدورة الزمنية اللازمة للمرتجعات (للمورد أو من العميل	.2	1	.17		VP		
RS 2.1	Source Cycle Time	الدورة الزمنية اللازمة لإتمام عمليات التوريد	.2	1	.18		G	.497	.089
RS 2.2	Make Cycle Time	الدورة الزمنية اللازمة لإتمام مراحل التصنيع	.2	1	.36		VG	.798	.287
RS 2.3	Deliver Cycle Time	الدورة الزمنية اللازمة لاتمام مراحل تسليم المنتج للعميل	.2	1	.46		VG	.79	.363
RS 2.4	Source Return Cycle Time	الدورة الزمنية اللازمة لإرجاع منتج غير مطابق للمورد	90	21	.28		-		
RS 2.5	Deliver Return Cycle Time	الدورة الزمنية اللازمة لإستدعاء منتج غير مطابق من السوق	7	1	.72		-		
RS 3.1	Identify Sources of Supply Cycle Time	الفترة الزمنية اللازمة لتحديد مصادر التوريد	.2	1	.1		VP		
RS 3.2	Select Supplier and Negotiate Cycle Time	الفترة الزمنية اللازمة لأختيار المورد والتفاوض معه	.2	1	.11		VP		
RS 3.3	Schedule Product Deliveries Cycle Time	الفترة الزمنية اللازمة لوضع جداول أوامر التوريد لمستلزمات الإنتاج	.2	1	.19		VG	.716	.136
RS 3.4	Receive Product Cycle Time	الفترة الزمنية اللازمة لإستلام طلبيات مستلزمات الإنتاج الواردة	.2	1	.26		G	.544	.141
RS 3.5	Verify Product Cycle Time	الفترة الزمنية اللازمة لفحص طلبيات مستلزمات الإنتاج الواردة والتأكد من مطابقتها للمواصفات	.2	1	.15		P	.372	.056
RS 3.6	Transfer Product Cycle Time	الفترة الزمنية اللازمة لتخزين الطلبيات الواردة بمخزن مستلزمات الإنتاج	.2	1	.09		VG	.716	.064
RS 3.7	Authorize Supplier Payment Cycle Time	الفترة الزمنية اللازمة لإتمام الإجراءات الخاصة بسداد مستحقات الموردين	.2	1	.1		E	1	.1
RS 3.8	Schedule Production Activities Cycle Time	الفترة الزمنية اللازمة لوضع جداول الإنتاج	10	7	.31	7	E	1	.31
RS 3.9	Issue Material Cycle Time	الفترة الزمنية اللازمة لصرف إحتياجات الإنتاج من المواد الخام من المخزن					-		
RS 3.10	Produce and Test Cycle Time	الفترة الزمنية اللازمة للإنتاج وإختبار المنتج للتأكد من مطابقته للمعايير و المواصفات القياسية	10	8	.61	8.344	VG	.8	.488
RS 3.11	Package Cycle Time	الفترة الزمنية اللازمة لتغليف المنتج قبل تخزينه					-		
RS 3.12	Stage Finished Product Cycle Time	الفترة الزمنية اللازمة للقيام بتخزين المنتج داخل مخزن الإنتاج التام					-		
RS 3.13	Release Finished Product To Deliver Cycle Time	الفترة الزمنية اللازمة لصرف المنتج من مخزن الإنتاج التام			.08		-		
RS 3.14	Receive and validate order +Determining delivery date	الفترة الزمنية اللازمة لإستلام وفحص الطلبات الواردة من إدارة المبيعات لتحديد الأرصدة المتاحة من المخزون وتحديد تاريخ تسليم الطلبات	48	24	.22	24	E	1	.22
RS 3.15	Receive product from warehouse +Pack product + Load vehicle	الفترة الزمنية اللازمة لإستلام المنتج التام و فحصه لتحميل و تستيف المنتج على الشاحنات لنقله للعميل وكذلك تجهيز كافة مستندات الشحن	72	24	.55	4	E	1	.55
RS 3.16	Ship Product Cycle Time	الفترة الزمنية اللازمة لنقل المنتج التام من موقع الإنتاج للعميل	3	1	.1	33.49	VP	.2	.02
RS 3.17	Receive & Verify Product Cycle Time	الفترة الزمنية اللازمة لتسليم المنتج للعميل وفحصه من قبل العميل			.13		-		
RS 4.1	Identify DM Sources of Supply Cycle Time	الفترة الزمنية اللازمة لتحديد مصادر توريد المواد الخام المباشرة	7	5	.86		-		

RS 4.2	Identify INDM Sources of Supply Cycle Time	الفترة الزمنية اللازمة لتحديد مصادر توريد المواد الخام الغير المباشرة	.2	1	.14		VP		
RS 4.3	Select DM Supplier and Negotiate Cycle Time	الفترة الزمنية اللازمة لأختيار المورد للمواد الخام المباشرة والتفاوض معه	30	14	.86		-		
RS 4.4	Select INDM Supplier and Negotiate Cycle Time	الفترة الزمنية اللازمة لأختيار المورد للمواد الخام الغير المباشرة والتفاوض معه	30	7	.14		-		
RS 4.5	Schedule DM Product Deliveries Cycle Time	الفترة الزمنية اللازمة لوضع جداول أوامر التوريد لمستلزمات الإنتاج المباشرة	2	1	.86	1.25	VG	.8	.688
RS 4.6	Schedule INDM Product Deliveries Cycle Time	الفترة الزمنية اللازمة لوضع جداول أوامر التوريد لمستلزمات الإنتاج الغير المباشرة	30	7	.14	34.661	VP	.2	.028
RS 4.7	Receive DM Product Cycle Time	الفترة الزمنية اللازمة لإستلام طلبيات مستلزمات الإنتاج المباشرة الواردة	30	7	.86	18.482	G	.6	.516
RS 4.8	Receive INDM Product Cycle Time	الفترة الزمنية اللازمة لإستلام طلبيات مستلزمات الإنتاج الغير المباشرة الواردة	60	7	.14	57.48	VP	.2	.028
RS 4.9	Verify DM Product Cycle Time	الفترة الزمنية اللازمة لفحص طلبيات مستلزمات الإنتاج المباشرة الواردة والتأكد من مطابقتها للمواصفات	1	.5	.86	.833	P	.4	.344
RS 4.10	Verify INDM Product Cycle Time	الفترة الزمنية اللازمة لفحص طلبيات مستلزمات الإنتاج الغير المباشرة الواردة والتأكد من مطابقتها للمواصفات	14	7	.14	12.269	VP	.2	.028
RS 4.11	Transfer DM Product Cycle Time	الفترة الزمنية اللازمة لتخزين الطلبيات الواردة من المواد المباشرة بمخزن مستلزمات الإنتاج المباشرة	1	.5	.86	.547	VG	.8	.688
RS 4.12	Transfer INDM Product Cycle Time	الفترة الزمنية اللازمة لتخزين الطلبيات الواردة من المواد الغير المباشرة بمخزن مستلزمات الإنتاج الغير المباشرة	14	7	.14	13.2	VP	.2	.028
RS 4.13	Authorize DM Supplier Payment Cycle Time	الفترة الزمنية اللازمة لإتمام الإجراءات الخاصة بسداد مستحقات الموردين للمواد الخام المباشرة	30	60	.86	53.732	E	1	.86
RS 4.14	Authorize INDM Supplier Payment Cycle Time	الفترة الزمنية اللازمة لإتمام الإجراءات الخاصة بسداد مستحقات الموردين للمواد الغير المباشرة	7	50	.14	52.378	E	1	.14
RS 5.1	Identify machines Sources of Supply Cycle Time	الفترة الزمنية اللازمة لتحديد مصادر توريد الماكينات	120	30	.86		-		
RS 5.2	Identify other INDM Sources of Supply Cycle Time	الفترة الزمنية اللازمة لتحديد مصادر توريد المواد الخام الغير المباشرة خلاف الماكينات	30	7	.14		-		

The aggregated weighted rates of the bottled water company's agility performance measures for the year ended December 31st 2010:

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
Node : AG									
AG 1.1	Upside Supply Chain Flexibility	مرونة سلسة الإمداد للإستجابة لزيادة الطلب الغير متوقعة	.2	1	.28		VP	.2	.056
AG 1.2	Upside Supply Chain Adaptability	مدى مرونة سلسة الإمداد للإستجابة خلال فترة زمنية محددة للزيادة الغير متوقعة في الطلب	.2	1	.53		E	.874	.463
AG 1.3	Downside Supply Chain Adaptability	مرونة سلسة الإمداد للإستجابة السريعة خلال أقل فترة زمنية ممكنة للنقص الغير متوقع في الطلب	.2	1	.19		VG	.608	.116
AG 2.1	Upside Source Flexibility	مدى قدرة أنشطة التوريد للإستجابة لزيادة الطلب الغير متوقعة	15	2	.33	15.717	VP	.2	.066
AG 2.2	Upside Make Flexibility	مدى قدرة مراحل التصنيع للإستجابة لزيادة الطلب الغير متوقعة	4	1	.4	4.333	VP	.2	.08
AG 2.3	Upside Deliver Flexibility	مدى قدرة إستجابة المراحل اللازمة لتسليم المنتج للعميل للزيادة الغير متوقعة في الطلب	3	1	.27	3.3	VP	.2	.054
AG 2.4	Upside Source Adaptability	مدى قدرة أنشطة التوريد للإستجابة خلال فترة زمنية محددة للزيادة الغير متوقعة في الطلب	.75	1	.35	.987	E	1	.35
AG 2.5	Upside Make Adaptability	مدى قدرة مراحل التصنيع للإستجابة خلال فترة زمنية محددة للزيادة الغير متوقعة في الطلب	.3	.7	.44	.675	E	1	.44
AG 2.6	Upside Deliver Adaptability	مدى قدرة إستجابة المراحل اللازمة لتسليم المنتج للعميل خلال فترة زمنية محددة للزيادة الغير متوقعة في الطلب	.15	.25	.21	.171	P	.4	.084
AG 2.7	Downside Source Adaptability	مدى قدرة أنشطة التوريد للإستجابة السريعة خلال أقل فترة زمنية ممكنة للنقص الغير متوقع في الطلب	.3	.6	.41	.527	E	1	.41
AG 2.8	Downside Make Adaptability	مدى قدرة مراحل التصنيع للإستجابة السريعة خلال أقل فترة زمنية ممكنة للنقص الغير متوقع في الطلب	.25	.3	.4	.257	P	.4	.16
AG 2.9	Downside Deliver Adaptability	مدى قدرة إستجابة مراحل تسليم المنتج للعميل للنقص الغير متوقع في الطلب وذلك خلال أقل فترة زمنية ممكنة	.25	.3	.19	.217	VP	.2	.038

The aggregated weighted rates of the bottled water company's cost performance measures for the year ended December 31st 2010:

Node ▲

Node : CO

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
CO									
CO 1.1	Supply Chain Management Cost	تكاليف إدارة سلسلة الإمداد	.2	1	.33		P	.256	.084
CO 1.2	Cost of Goods Sold	تكلفة البضاعة المباعة	.2	1	.67		P	.312	.209
CO 2.1	Freight expense	مصاريف النقل	.17	.11	.65	.17	VP	.2	.13
CO 2.2	Direct marketing expense	مصاريف تسويقية مباشرة	.08	.04	.07	.08	VP	.2	.014
CO 2.3	Direct sales expense	مصاريف بيعية مباشرة	.2	.15	.21	.21	VP	.2	.042
CO 2.4	Administrative expense	مصاريف ادارية	.02	.01	.07	.01	E	1	.07
CO 2.5	Cost to Make	تكلفة مراحل التصنيع	.2	1			-		
CO 3.1	M Cost	تكلفة المواد	.75	.54	.56	.67	P	.4	.224
CO 3.2	L Cost	تكلفة الأجور	.15	.09	.15	.14	VP	.2	.03
CO 3.3	Indirect Costs Related To Making Product	التكاليف الصناعية الغير مباشرة	.25	.14	.29	19	VP	.2	.058

The aggregated weighted rates of the bottled water company's asset management performance measures for the year ended December 31st 2010:

Node ▲

Performance Attribute Code	Attribute Name	Arabic Attribute Name	MIN	MAX	Weight	Annual performance	Rate	Rate Value	Weighted Rate
AM									
Node : AM									
AM 1.1	Cash-to-Cash Cycle Time	الدورة الزمنية للنقدية	.2	1	.44		VG	.686	.302
AM 1.2	Return on Supply Chain Fixed Assets	العائد على الأصول الثابتة بسلسلة الإمداد	.1	.14	.12	-.06	VP	.2	.024
AM 1.3	Return on Working Capital	العائد على رأس المال العامل	.3	.54	.18	-.01	VP	.2	.036
AM 1.4	Capacity Utilization	الأستخدام الأمثل للطاقة الإستيعابية	.2	1	.26		VG	.623	.162
AM 2.1	Days Sales Outstanding	متوسط فترة التحصيل	77	57	.54	54	E	1	.54
AM 2.2	Inventory Days of Supply	متوسط فترة التخزين	26	16	.33	20	G	.6	.198
AM 2.3	Days Payable Outstanding	متوسط فترة السداد	30	44	.13	31	P	.4	.052
AM 2.4	Operating Rate	(نسبة التشغيل (معدل التشغيل	85	95	.22	58.629	VP	.2	.044
AM 2.5	Downtime	نسبة التوقف	.2	1	.38		VG	.681	.259
AM 2.6	% spoilage Material	نسبة الهالك من المواد الخام	3	1	.4	1.211	VG	.8	.32
AM 3.1	Scheduled Downtime	نسبة التوقف المخططة	.2	1	.69		VG	.8	.552
AM 3.2	Unscheduled Downtime	(نسبة التوقف الفجائية (الغير مخططة	.2	1	.31		G	.416	.129
AM 4.1	Scheduled Process Downtime	نسبة التوقف المخططة الناتجة عن توقف فى عمليات التشغيل لأسباب خلاف أعطال الماكينات	16	14	.33	14.134	VG	.8	.264
AM 4.2	Scheduled Equipment Downtime	مدة التوقف المخططة الناتجة عن صيانة الماكينات	5	4	.67	4.25	VG	.8	.536
AM 4.3	Unscheduled Process Downtime	نسبة التوقف الفجائية (الغير مخططة) الناتجة عن توقف فى عمليات التشغيل لأسباب خلاف أعطال الماكينات	25	18	.64	29.318	VP	.2	.128
AM 4.4	Unscheduled Equipment Downtime	نسبة التوقف الفجائية (الغير مخططة) الناتجة عن توقف الماكينات	7	5	.36	5.496	VG	.8	.288

APPENDIX 12- Feedback on implementing supply chain management key performance indicators (SCM KPIs) system in the bottled water Company

"Feedback on implementing supply chain management key performance indicators (SCM KPIs) system in the bottled water Company"

Purpose

Get and assess the feedback on implementing the SCM KPIs system in the bottled water company through identifying costs and benefits, the perceived advantages and disadvantages of implementing this system and suggestions for improving it.

Participant

The research informant (business planning manager)

Questions

- What changes in company systems and processes were required to apply supply chain management key performance indicators (SCM KPIs) system?

  No changes were required to apply system as the researcher exerted a great effort in analysing the role of each department to match it to the supply chain functions. This resulted from the fact that in 2010 each department of the bottled water company used to carry out several roles of the supply chain. For example, the planning department was responsible for some of the planning (PLAN) and purchasing (SOURCE) tasks, in addition to other tasks related to the factory Quality Dept. (MAKE). Therefore, no clear separation exists between departments' roles in relation to the supply chain functions.

- What were the costs, if any, of making the necessary changes, in terms of staff time, systems and technology?

  Only one data entry was hired.

- In your opinion, what are the benefits of implementing SCM KPIs system?

  The benefits are as follows:

  1- Having a database including all information related to supply chain functions which helps monitor the efficiency of each function and set the necessary strategies.

  2- Providing a clear vision for all department heads in relation to the supply chain stages and functions and how each function affects the other.

3- Applying a coding system for all items related to the supply chain functions such as materials, products. ..etc.

4- Providing a vision for the separation between department functions in order to coincide with supply chain stages to give a better result especially that the bottled water company will have SAP system soon, which will ultimately necessitate this separation.

- How do SCM KPIs system fit into companies' overall responsible supply chain operational strategy and implemented processes?

The system information and research findings focused on the weak points of supply chain functions and provided a clear vision for the top management in relation to the problematic areas. For example, the system provided very critical information concerning machines and factory operation efficiencies which will be focused on in the coming period in order to find out the root problem.

- What are the perceived advantages and disadvantages of using SCM KPIs system?

Advantages:

1- Monitoring direct and indirect materials sourcing with respect to the performance of each supplier and in relation to planned vs. delivered quantities. In addition to monitoring accuracy in the delivery time which is a main issue in measuring Egyptian suppliers' performance.

2- Monitoring percentage of spoilage materials regularly in order to handle any problem in relation to the quality of the supplied materials.

3- Monitoring scheduled and unscheduled equipment downtime in order to measure machines efficiency in relation to its origin and its effect on the ROI, in addition to monitoring the performance of the maintenance team.

4- Monitoring factory production process (MAKE) in relation to the outcome of each production hour and analysing and solving any problem which affects the outcome per hour.

5- Staff orientation with regards to all supply chain stages, terms and advantages.

Limitations:

1- The section of "Average of Month Downtime" lacks monitoring other stoppages such as workers rest or materials change such as label or shrinks. Adding these stoppages would help in calculating the actual production efficiency.

2- In the section of "Average make cycle time of month AND Average % of month operating rate" the number of actual operating hours per shift vs. planned should be added in order to calculate the operating rate per hour not per shift and compare it to the theoretical or potential capacity of the production lines

3- More data about suppliers' performance and spoilage should be included in order to clearly differentiate between the machines spoilage per material and suppliers' spoilage.

- In your opinion, how can this system be improved?

Yes, it can be improved to coincide with the current change in the bottled water company specifically and the group as a whole. This change is heading towards establishing a supply chain department responsible for all supply chain stages in each company so the bottled water company will have an operation planning manager responsible for supply chain planning functions only and a procurement manager responsible for the sourcing. Thus, the system could be changed to include the new functions of each department in addition to their KPIs.