A SUPPLY CHAIN PERFORMANCE MEASUREMENT PROCESS FOR THAI AUTOMOTIVE INDUSTRY

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วิทยานิพนธ์ฉบับนี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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ด้วยความสำคัญของสายโซ่อุปทานซึ่งเป็นที่ตระหนักกันอย่างดีในธุรกิจ จึงมีการพัฒนาการวัดสมรรถนะของธุรกิจในแนวคิดของสายโซ่อุปทานขึ้นหลากหลายวิธี แต่วิธีการวัดเหล่านั้นมีปัญหาในการปฏิบัติอยู่บ้างเนื่องจากมีวิธีการที่ยุ่งยากและขาดการวัดในบางประเด็น อุตสาหกรรมยานยนต์ไทยซึ่งประกอบด้วยธุรกิจขนาดย่อมและขนาดกลางเป็นส่วนใหญ่ จึงควรที่จะมีกระบวนการสำหรับใช้ในวัดสมรรถนะของสายโซ่อุปทานของอุตสาหกรรมเอง ซึ่งควรจะครอบคลุมประเด็นด้านผลิตภาพ คุณภาพ ทรัพยากรบุคคล และสารสนเทศพื้นฐาน

วิทยานิพนธ์นี้นำเสนอกระบวนการวัดสมรรถนะของสายโซ่อุปทาน ซึ่งพัฒนาขึ้นจากผลงานวิจัยที่ผ่านมาด้านการวัดสมรรถนะในแง่มุมต่าง ๆ เช่น การวัดสมรรถนะโดยทั่วไป การวัดสมรรถนะในสายโซ่อุปทาน และการวัดสมรรถนะในกิจการขนาดย่อมและขนาดกลาง กระบวนการนี้ใช้สำหรับวัดสายโซ่อุปทานตั้งแต่ผู้ขายวัตถุดิบโดยตรงให้กับกิจการไปจนถึงลูกค้าของกิจการโดยตรง โดยพิจารณาจากสามประเด็นซึ่งได้แก่ กระบวนการที่รับผิดชอบ (ซึ่งพัฒนาจากหลักการ Supply Chain Operations Reference (SCOR)) ตัวชี้วัดจากมุมมองของสายโซ่อุปทาน และระดับการจัดการ

กระบวนการที่พัฒนาขึ้นได้นำไปทดลองใช้กับระดับปฏิบัติการในโรงงานผลิตชิ้นส่วนยานยนต์ขนาดเล็กแห่งหนึ่งในประเทศไทย คาดว่ากระบวนการนี้จะทำให้เกิดความตื่นตัวในแนวคิดด้านสายโซ่อุปทานและเป็นการริเริ่มกระบวนการการวัดสมรรถนะและการปรับปรุงในสายโซ่อุปทาน ทั้งในบริษัทที่เข้าไปทดสอบ ตลอดจนอุตสาหกรรมยานยนต์โดยรวม

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In current business environment, the importance of supply chain is broadly recognised, and there have been developments of performance measurement in the supply chain concepts from various points of view. However, there are some difficulties in implementation because of their complicated approaches and some lacked measurement areas. In Thai automotive industry where small and medium sized enterprises (SMEs) dominate, a comprehensive but easy to use supply chain performance measurement framework can be useful. Issues that should be addressed in the measurements for the industry include productivity, quality, human resource, and IT fundamental.

In this thesis, a supply chain performance measurement framework is proposed. Its development was based on previous performance measurement researches in different areas such as general performance measurement, performance measurement in supply chain environment, and performance measurement in SMEs. The framework aimed to measure the performance of supply chain from direct supplier to direct customer based on three different perspectives: responsible processes (based on Supply-Chain Operations References (SCOR)), measurement areas (based on supply chain focus), and managerial levels.

The framework was tested at the operational level in a small automotive company in Thailand. It is expected that it will bring awareness of the supply chain concepts, and provides an initial step of the performance measurement and improvement process of supply chain to the case company and the industry in general.

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CHAPTER 1

INTRODUCTION

1.1. Background

In the current competitive economy, Supply Chain Management (SCM) is broadly implemented in various industries, and the automotive industry is one of the most interested research topics and the result is reported by many researchers (Womack *et al*, 1990 and Hines *et al*, 2000). As seen in these trends, the importance of Supply Chain is well recognised and its activity is getting more and more competitive in global scale.

Performance Measurement is an essential factor to achieve effective planning and control as well as better decision making for performance improvements. There are many studies regarding performance measurement. For example, perhaps the best known performance measurement framework is the Balanced Scorecard introduced by Kaplan and Norton (1992), and the framework is broadly introduced in many companies. However, the in SC environment, the performance depends on the quality of the relationship that extends from upstream to downstream partners (Christopher, 1998), which the Balanced Scorecard doesn't cover fully. This suggests that the performance measurement also should have wider focus based on SC concepts not only in a single organisation but also between/through suppliers and customers as well. Various studies attempt to meet the need on performance measurement in supply chain environment by compensating the lacked area of measurements and by applying the supply chain focus in performance measurement. Supply-Chain operations reference (SCOR) model is developed as the first cross-industry framework for evaluating and improving enterprise-wide supply chain performance and management (Stewart, 1997). And, there are also several performance measurement frameworks in supply chain environment.

In Thailand, the automotive industry is considered to be one of the most important industries (NSEDB). NSEDB set the Vision 2011 as "Thailand is the automotive production base in Asia that adds value to the country with strong domestic supplier base" (TAI, 2002). Thai automotive industry developed with Foreign Direct Investment (FDI) by multinational automotive manufacturers. The development phases are: Simple Assembly Phase, First Phase of Localization, Second Phase of Localization, Rapid Growth Phase, Liberalisation Phase, Slow Down, and Recovery and Growth Phase. Now, the industry has recovered from the recession and has been developing gradually. In the developing business economy like in Thailand, the linkages between foreign and domestic companies between larger companies such as Multinational Corporations (MNCs) and smaller companies such as Small and Medium Enterprises (SMEs) are crucial not only to the competitiveness of individual company and but also to the future development of both the host country and involved companies (Dhanani and Scholtès, 2002). In this case, the SC concepts could be adopted and can contribute to the future development focusing not only on the individual company but also on the linkages between suppliers and customers.

The study on Thai automotive industry by NESDB (2003) identified two critical issues: "the dependence to multinational automotive companies" and "the local suppliers' competitiveness." The later one, the competitive issue includes "the low levels of productivity," "lack of capability to produce high precision, and complex parts," and "weak upstream supporting industries such as tools and machinery, mold and die, and steel." There are other issues. Another study revealed that the value-added counts less than 20 per cent of value-added in the manufacturing sectors (Dhanani and Scholtès, 2002) although SMEs dominate the biggest portion in terms of the number of companies (Limskul, 1998). SWOT analysis of Thai automotive industry developed by TAI (2002) gave the insight of the issue in "Human Resources" and "IT fundamental."

The case SME in Thai automotive industry is a manufacturer of casting products such as Fly Wheels, Hubs, Drum Brakes and Pulleys at 3rd or 4th tier of supply chain. An automotive customer outsources casting parts to the company because the company own proper facilities to produce casting parts and gives technical assistance to the company when the product quality has significant problems. From the supplier-customer relationship point of view, the relationship is desirable for both companies although there are some unfavourable contracts to the company too. At present, the company considers the customer as their business focus and tries to meet the customer orders at the first priority although they have other customers in other industries.

In Thai automotive industry, it is not too much to say that the requirement for the supply chain development is the performance improvement of SME suppliers. And, for the case company, the performance measurement in supply chain concepts will be a useful tool to meet the customer satisfaction.

1.2. Statement of the Problems

Although there are various studies on performance measurements in general as well as in supply chain environment, there is still a lack of integration between the existing performance measurement methods and practical requirements for the supply chain management (Chan *et al*, 2003). Hoek (1998) argues that traditional performance measures may limit the possibilities to optimise supply chains, as management does not see supply chain wide areas for improvement.

Performance measurements in supply chain context attempt to deal with performances in the individual company and the links with suppliers and customers. Although the ultimate goal would be the performance measurement of the total supply chain, the supply chain performance measurements start from the minimum linkages since it is difficult or almost impossible to measure the total supply chain performance because of the possible boundary between/through the supply chain. The SCOR model is proposed as a process based performance measurement system in supply chain context with the core processes, Plan, Source, Make and Deliver (and Return) which cover the internal and external (supplier-side and customer-side) activities. Each core process is decomposed into sub-processes at the second level and then process elements at the third level. This model is implemented to many companies in the world. However, the system seems to be complicated to apply to any company which requires either a new or better supply chain performance measurement system. There are also various other studies giving different focus in the supply chain management by many researchers such as Gunasekaran *et al* (2001) or Gilmour (1999). As well as the performance measurement framework, the selection of performance measures is discussed by various major area of study (Neely, 1997 or Beamon, 1999). Hoek (1998) and Bowersox *et al* (2002) argued that the influence of the position of company in the chain (supplier, manufacturer, wholesaler, service supplier) to their contribution and relevant measures, and the level of integration and the strategic approach may affects the relevance of measures. Hence, the performance measures and performance measurement system must be designed under the environment where the company belongs to.

In SMEs, as Morgan (2004) claimed, while many large organisations successfully implemented the supply chain philosophy, many SMEs have not succeeded in the supply chain development. It might be also said that the supply chain performance measurement is merely implemented and practiced in SMEs. Regarding the performance measurement, Neely *et al*, (1995) revealed a key finding of a survey on performance measures in UK SMEs was that the cost of measurement is an issue of great concern to managers in SMEs. A respondent commented "for SMEs often the best justification is 'feel', even when the numbers don't add up. Measurement is a luxury - success and failure are obvious."

In the case company, despite the priority to the automotive customer, they still have problems on internal defects, defects detected by customer or late delivery. They recognise those problems, and the data is collected mostly on quality issues. However, the data is just "records" of numbers not "measures" for improvements. As a respondent of the previous survey in UK SMEs said, the case company also rely on manager's 'feel' to achieve better scheduling and performance.

It is necessary to develop a comprehensive, but "easy to use" and suitable performance measurement system in supply chain context at the lower tier of supply chain being mostly dominated by SMEs that may have lower performance and lower awareness of performance measurement in supply chain context.

1.3. Objectives of the Research

The objective of the research is:

- To propose a supply chain performance measurement framework for Small and Medium sized Enterprises (SMEs) in Thai automotive industry

1.4. Scope of the Research

The scope of the research is limited to the followings:

- The performance measurement is limited to a part of supply chain from the direct supplier to the direct customer
- Performance areas are categorised into three types; Responsible Process types including Plan, Source, Make, Deliver and Others, Measurement Area types including Cost/Financial, Quality/Accuracy, Inventory/Waiting and Time/Flexibility, and Managerial Levels including Strategic, Tactical and Operational
- Performance measures at Operational level are selected as shown in Table 1.1.
- The framework is tested by applying to a small manufacturer of casting products in Thai automotive industry

Table 1.1: Performance Measures in the case SME

Operational Level		Measurement Area Types			
		Cost / Financial	**Quality / Accuracy**	**Inventory / Waiting**	**Time / Flexibility**
Responsible Process Types	**Plan** Information Flow and Planning	▪	▪	▪ % of On-Time Delivery to Customer (P1)	▪
	Source Inbound Logistics	▪ Raw Material Inventory as a % of Total Purchase (S1)	▪	▪	▪ % of On-Time Delivery from Suppliers (S2)
	Make Manufacturing Operations	▪	▪ % of Internal Defects (M1)	▪	▪
	Deliver Outbound Logistics	▪	▪ Defects at Customer as a % of Total Delivery (D1)	▪	▪ Delivery Schedule Change from Customer (D2)
	Others Others or Total	▪	▪ Average Absence (O1)	▪	▪

1.5. Expected Benefits

A supply chain performance measurement framework should deliver

(1) Awareness of supply chain concepts and performance measurement in supply chain context in a case company

(2) An initial step for further performance measurement and improvements in a case company in a form of Performance Measurement Template (Table 1.2)

Table 1.2: An Example of Performance Measurement Template

Process	Delivery
Responsible Department	Production Control
Measurement Area	Quality / Accuracy
Measure	Number of Defects found at Customer
Business Objectives	Improve Customer Satisfaction
Latest Result	2.1 % at July 2004
Target	0.5 % at the end of the year 2004
Result	2.0 % at August 2004
Formula for the Measure	Sum up the Claims on Defects
Source of Data	Claims from Customer
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the delivery results and investigate unexpected results
Notes	Current delivery performance is getting better by improved internal process. It is necessary to cooperate with QC/QA to improve the defects detection rate before shipping.

1.6. Research Procedure

(1) Study and understand the related researches

- Study the supply chain concept
- Study the existing performance measurements
- Identify success factors in the industry

(2) Develop a supply chain performance measurement framework

- Analyse existing performance measurement framework
- Develop a framework

(3) Test the framework in a case company

- Study the background of the company and the industry
- Collect necessary data for the selected performance measures
- Analyse and discuss the investigated results
- Set an initial step of performance improvement
- Suggest improvements

CHAPTER 2

LITERATURE REVIEW

2.1. Supply Chain

In the current competitive economy, companies are not competing with companies, the supply chains compete with each other. (Christopher, 1992).

2.1.1. Key Processes and Emphases of Supply Chain

There are a lot of publications discussing about the Supply Chain. Lambert and Cooper (2000) identified the key supply chain processes as: Customer relationship management, Customer service management, Demand management, Order fulfilment, Manufacturing flow management, Procurement, Product development and commercialisation, Returns. Christopher (1998) confirms that the supply chain performance depends on the quality of the relationship that extends from upstream to downstream partners. In the supply chain context, logistics is one of the most important areas to manage; it includes order management, inventory, transportation, warehousing, materials handling, and packaging (Bowersox, 2002). New (1996) identified the dominant interpretation of Supply Chain covers around three areas: Effective purchasing distribution, A focus on long-term relationships between trading partners, and the Operational integration of trading organisations.

However, as seen above and New (1996) argues, the supply chain concept derives from many directions, which result in many different norms or words such as

Supply Chain, Value Chain, or Value Stream. The Value Chain (Porter, 1985) was described with competitive advantages. The value chain involves five primary and four support activities in a company. The primary activities include Inbound Logistics, Operations, Outbound Logistics, Marketing & Sales, and Service. The support activities include Procurement, Technology Development, Human Resource Management, and Firm Infrastructure. Each activity involves some other sub-activities within them depending on the impacts to the competitiveness, and all of those activities are linked each other to maximise the competitive advantages. The value chain is not limited within the company, but it is also linked to supplier and customer depending on its focus scale. Supply Chain is basically a synonym of Value Chain. Supply Chain emphasises the activities of supply from the supplier to the buyer to the final customer, whereas Value Chain emphasises where the value adding elements exist within and between the functions of the firm. Supply Chain consists of firms collaborating to leverage strategic positioning and to improve operation efficiency (Bowersox, 2002).

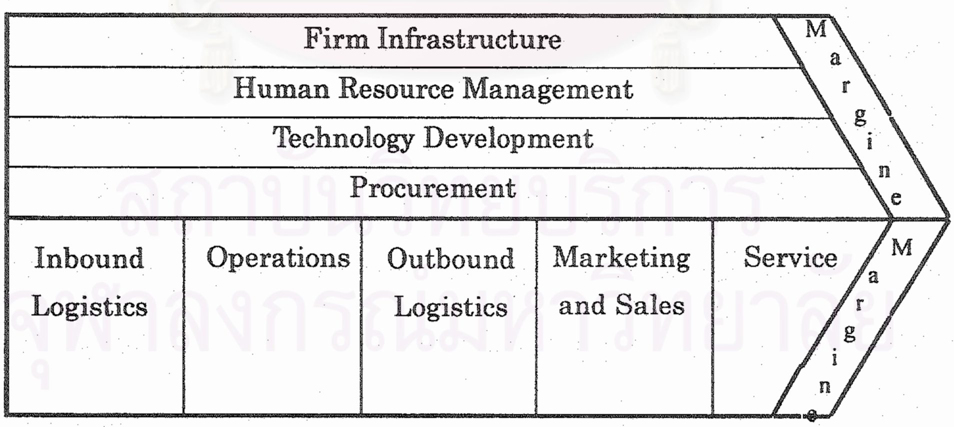


Figure 2.1: Value Chain

To optimise the supply chain within the company and through the supply chain from the raw materials (upstream) to the end customers (downstream), the information system integration and the cooperative and collaborative relationship between suppliers and customers are necessary. The information system integration leads to the significant paperwork reduction (McLaughlin *et al*, 2003), the cost reduction (Anandarajan *et al*, 1998), the lead time reduction, or the communication improvements.

In terms of the supplier-customer relationship, there are many discussions. Some different researchers classified the relationships into several stages depending on mostly similar concepts; Stevens (1989) named four stages as Baseline, Functional Integration, Internal Integration and External Integration, Spekman *et al* (1998) named four stages as Open Market Negotiations, Co-operation, Co-ordination and Collaboration, Stuart and McCutcheon (1996) named three stages Initiation, Development and Maintenance from the initial strategic alliances. In general, strategic match, information openness, information system integration, performance feedback, technological assistance or risk sharing are the critical requirements as well as the barriers to over come (Stuart and McCucheon, 1996, Spekman *et al*, 1998, and Zsidisin and Ellram, 2001). At the high level of the supplier alliance, the suppliers are involved into the product development phase which requires the technological and managerial openness and mutual dependence from involved companies (Liker *et al*, 1998). In this case, the requirements for supplier to be got involved are the high technical capabilities supplying complex components or subsystem or the smooth CAD/CAM data exchange.

To minimise or eliminate the wastes in the operation and to response to the customer demand flexibly, the concept of Lean supply and Agile supply are studied. Lean Supply (Womack *et al*, 1990 and Dimancescu *et al*, 1997) was derived from

Toyota and broadly spread to the automotive industry and the concepts and the processes to achieve it was summarised by Hines and Taylor (2000) in their report. The major concept of the Lean Supply is the elimination of Seven Wastes: Overproduction, Defects, Unnecessary Motion, Inappropriate Processing, Unnecessary Inventory, Transportation, and Waiting. The Lean Supply works well where the demand is relatively stable and hence predictable and where variety is low (Christopher and Towill, 2001). On the other hand, where the demand is unstable and the customer requirement for variety is high, the high degree of agility is required; this model is Agile Supply. The relationship with Qualifier & Winners (Hill, 1993) and Lean and Agile supply is crucial to the supply management; cost and reliable delivery are the main drivers of Lean, however product availability and services are the priority of Agile. Depending on the qualifiers and winners as well as the demand fluctuation along the long supply chain from upstream to downstream, the combined model of Lean and Agile supply is proposed (Christopher and Towill, 2001, Prince and Kay, 2003). There is another approach to the demand and variety changes by adapting the batch production to the small and medium-sized enterprises (Cooney, 2002). There would be potential approaches to the demand uncertainty (Waddington *et al*, 2002) depending on the market condition, corporate strategy, and supplier/customer relationships.

The linkages and the initiatives of organisations are broadened to the Cluster concept (Porter, 1998 and Magretta, 1999). Clusters are geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions in particular fields that compete but also cooperate. The cluster development requires the government's supports and initiatives including nationally and regionally. One form of the cluster is seen as a potential explanation of supplier parks (Morris *et al*, 2004). The close linkages with suppliers, customers, and other institutions contribute importantly not only to efficiency but to the rate of improvement and innovation.

2.1.2. Supply Chain in Developing Country and SMEs

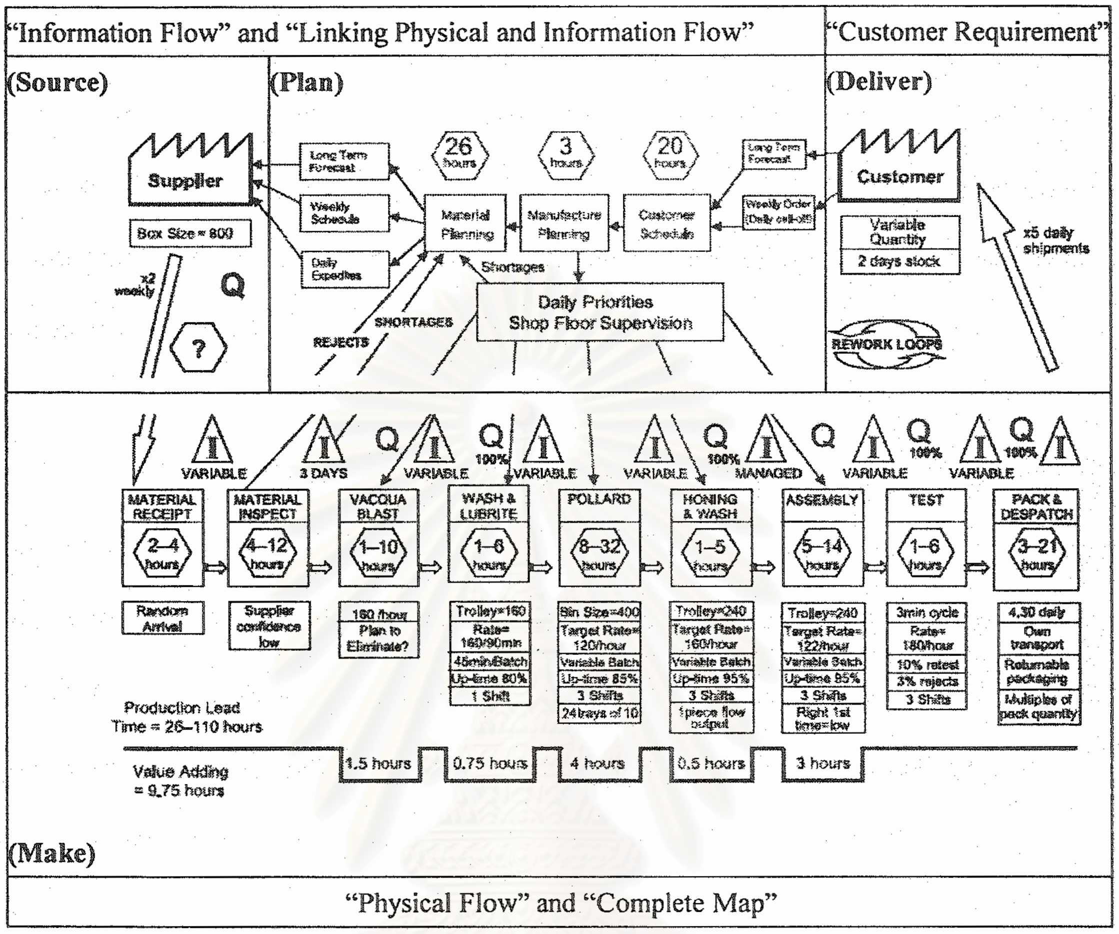
In the developing business economy like in Thailand promoting the Foreign Direct Investment (FDI) and the technology enhancement (Itoga, 1998), the linkages between foreign and domestic companies, between larger companies such as Multinational Corporations (MNCs) and smaller companies such as Small and Medium Enterprises (SMEs), and between manufacturing companies such as Parts/Components Suppliers and equipment suppliers such as Supporting Industries are crucial not only to the competitiveness of domestic companies and but also to the future development of both the host country and involved companies. For the foreign companies, local procurement can lower production costs, allow greater specialisation and flexibility, and better adaptation of technology and production to local conditions. For the domestic suppliers and the government, the business environment can raise their output and employment. In the development process, knowledge and skills can flow and shared between the linked companies, with beneficial impacts on production efficiency, productivity growth, technological and managerial capabilities and market diversification. Finally for the host country, linkages can stimulate economic activity and, where local inputs substitute for imported ones, benefit the balance of payments. The increased manufacturing capabilities of suppliers can in turn spill over to the rest of the economy (Dhanani and Scholtès, 2002).

Focusing on SMEs, Morgan (2004) claimed that while many large organisations successfully implemented the supply chain philosophy, many SMEs have not succeeded in the supply chain development. Very small enterprises often do not have the time, resources or information to undertake the analyses required for optimisation activities. Medium sized enterprises may have the information as their management system develops, but they lack the skills to interpret and apply it. These are real problems and they are global problems.

2.1.3. Diagnostic Tools

Big Picture Mapping explained by Hines and Taylor (2000) is derived from Toyota model of diagnostic tool. The details are described by Rother and Shook (1998). Understanding of entire processes is useful to help visualise the material and information flows, to show linkages between information and physical flows, to see the relationship with suppliers and customers, to help us see where wastes are, or to pull together the lean thinking principles. Also, this big picture helps senior managers to set the direction of improvement and helps line managers to develop detailed mapping and involve suppliers and customers with wider workforces. Big Picture Map, prepared five phases of investigations; starting with Phase1: Customer Requirement, Phase2: Information Flows, Phase3: Physical Flows, Phase4: Linking Physical and Information Flow, and completing with Phase5: Complete Map.

The areas investigated in the Big Picture Mapping are almost the same as the core processes in the Supply-Chain Operations References (SCOR) model appearing in the later section. Big Picture Mapping could be a powerful tool used when it is necessary to identify the actual business processes and to eliminate the wastes for further process improvement. Figure 2.2 and Table 2.1 illustrate the similarity of areas seen in Big Picture Mapping and SCOR model.



Source: Adopted from Hines and Taylor (2000) and modified

Figure 2.2: Example of Big Picture Map and the similarity with SCOR model

Table 2.1: Comparison of Big Picture Mapping and SCOR model with their similarity

Big Picture Mapping	Common Description	SCOR model
Customer Requirement	Outbound Logistics	Delivery Return
Information Flow	Information Flow	Plan
Physical Flow: Inbound Flows of raw material and/or key components	Inbound Logistics	Source
Physical Flow: Internal Processes	Manufacturing Operations	Make
Linking Physical and Information Flow	Production Control	Plan

2.2. Performance Measurement

Performance measurement is a topic which is often discussed but rarely defined (Neely *et al*, 1996). Literally the performance measurement is the process of quantifying action, where measurement is the process of quantification and action correlates with performance.

In business context, performance can be defined as the efficiency and effectiveness of action. Here, the effectiveness refers to the extent to which customer requirements are met, while efficiency refers to a measure of how economically the firm's resources are utilised to provide a given level of customer satisfaction. The definitions of performance measurement, performance measure, and performance measurement system are given as follows (Neely *et al*, 1995 and 1996):

- Performance measurement:

"The process of quantifying the efficiency and effectiveness of action"

- Performance measure:

"A metric used to quantify the efficiency and/or effectiveness of action"

- Performance measurement system:

"The set of metrics used to quantify the efficiency and effectiveness of actions"

2.2.1. Performance Measurement in General

A performance measurement system can be examined at three different levels (Neely *et al*, 1995) which indicate the importance to link the performance measures and performance measurement system to the business environment. Figure 2.3 illustrates a framework for performance system design:

- The individual performance measures
- The set of performance measures - the performance measurement system as an entity
- The relationship between the performance measurement system and the environment within which it operates

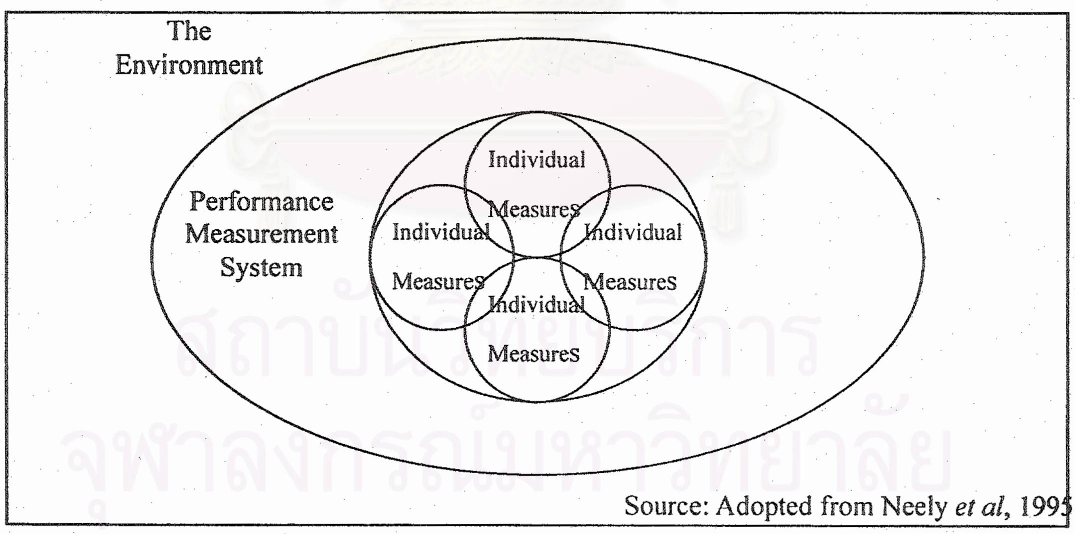
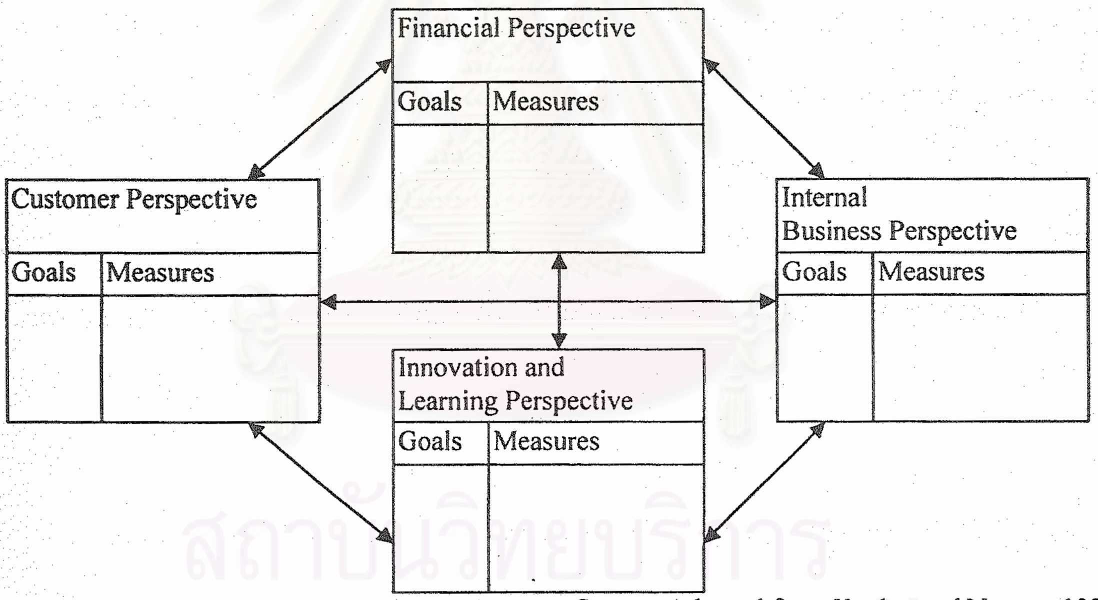


Figure 2.3: A Framework for Performance Measurement System Design

Perhaps the best known performance measurement framework is the Balanced Scorecard by Kaplan and Norton (1992), which is based on the principle that a performance measurement system should provide managers with sufficient information to address the following four areas of questions:

- How do we look to our shareholders (Financial perspective)?
- What must we excel at (Internal business perspective)?
- How do our customers see us (Customer perspective)?
- How can we continue to improve and create value (Innovation and learning perspective)?



Source: Adopted from Kaplan and Norton, 1992

Figure 2.4: The Balanced Scorecard

To aim the continuous improvement, a performance measurement template is useful. The Balanced Scorecard is a good example to use the measure to achieve the target. Neely *et al* (1997) also gave template called Performance Measure Record Sheet. It addresses the Title, Purpose, Relationship to business objectives, Target, Formula, Frequency, Who measures, Source of data, Who acts on the data, What do they do, and Notes and comments on a sheet. The sheet describes more details than the Balanced Scorecard does.

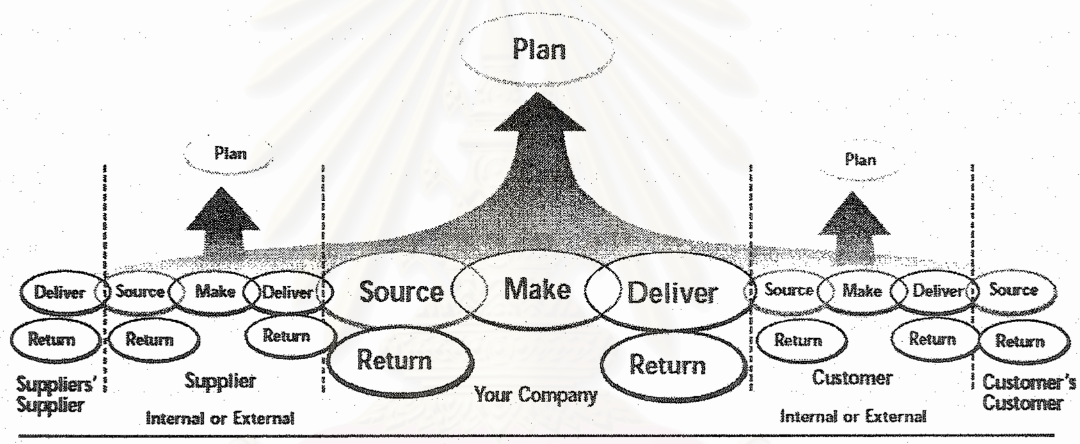
2.2.2. Performance Measurement in Supply Chain

Various researchers argue the problems of performance measurement in supply chain. Chan *et al* (2003) argues that there is still a lack of integration between the existing performance measurement methods and practical requirements for the supply chain management. Hoek (1998) points out that traditional performance measures may limit the possibilities to optimise supply chains, as management does not "see" supply chain wide areas for improvement.

Stewart (1997) introduced Supply-Chain operations reference (SCOR) model released by Pittiglio Rabin Todd & McGrath's (PRTM) and Advanced Manufacturing Research (AMR) as the first cross-industry framework for evaluating and improving enterprise-wide supply chain performance and management. SCOR is designed to enable companies to communicate, compare and develop new or improved supply chain practices from companies both within and outside of their industry segment. The SCOR model is process based approaches featuring four levels of supply chain management; Level 1 provides a broad definition of the Plan, Source, Make, and

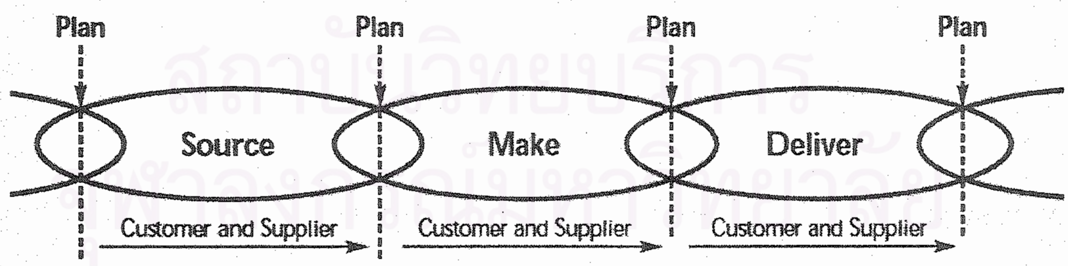
Deliver (and Return in newer versions) process types, Level 2 defines core process categories, Level 3 provides the information it need to plan and set goals successfully for its supply chain improvements through detailed process element information for each level 2 category, and Level 4 focuses on implementation.

The Figure 2.5 shows the five processes; Plan, Source, Make, Deliver, and Return, and links within a company and through the supply chain. And, the Figure 2.6 shows the chain of Source, Make and Deliver, and Plan as the facilitator of the links.



Source: Adopted from Supply-Chain Council (2003)

Figure 2.5: Five Distinct Management Processes of SCOR model



Source: Adopted from Supply-Chain Council (2003)

Figure 2.6: Plan, Source, Make, and Deliver links in SCOR model

SCOR does not attempt to describe every business process or activity including Sales and marketing (demand generation), Research and technology development, Product development, some elements of post-delivery customer support. Moreover, SCOR assumes but does not explicitly address Training, Quality, Information Technology (IT), and Administration (non SCM).

Similar to SCOR model, Chan *et al* (2003) proposed a process based performance measurements which decompose the processes into layers of structure; core processes, sub-processes and performance measures for each sub-process based on general view of supply chain, which is the material flow from suppliers, inbound logistics, core manufacturing, outbound logistics, marketing & sales, and customers. However, the framework seems to be complicated when adapted to the real world although it gives comprehensive results when implemented suitably because the result is given by a score, which have not be seen in any other performance measurements as far as studied.

There are also various studies regarding performance measurement in supply chain.

Gunasekaran *et al* (2001 and 2004) also provides a metrics categorised into three operational levels; Strategic, Tactical, and Operational, giving financial and non-financial measures based on the four links of an integrated supply chain appeared in SCOR model. The short descriptions of each operational level are show as follows:

- Strategic Level:

  Measures at this level influence the top level management decisions, reflecting investigation of broad based policies, corporate financial plans, competitiveness and level of adherence to organisational goals

- Tactical Level:

  Measures at this level deal with resource allocation and measure performance against targets to be met in order to achieve results specified at the strategic level. Measurement of performance at this level provides valuable feedback on mid-level management decisions

- Operational Level:

  Measurements and metrics at this level require accurate data and assess the results of decisions of low level managers. Supervisors and workers are to set operational objectives that, if met, will lead to the achievement of tactical objectives

Gilmour (1999) examines the functional capabilities in supply chain presented based on basic supply chain concept. Gilmour (1999) described a framework which can be used to evaluate supply chain processes with eleven capabilities in supply chain operations in three categories: Customer-driven supply chain, Efficient logistics, Demand-driven sales planning, Lean manufacturing, Supplier partnering, Integrated supply chain management as Process capabilities, Integrated information systems and Advanced technology as Information technology capabilities, and Integrated performance measurement, Teamwork and Aligned organisation structure as Organisation capabilities.

2.2.3. Performance Measurement in SMEs

In SMEs, it is important for these companies to be able to select and to utilise only the most critical performance indicators because their resources and knowledge bases are usually strongly restricted Hvolby and Thorstenson (2000). In addition to the limited resources and knowledge, another difficulty to implement the performance measurement was found by a survey on UK SMEs (Neely *et al*, 1995): cost of measurement is an issue of great concern to managers in SMEs. A respondent commented "for SMEs often the best justification is 'feel', even when the numbers don't add up. Measurement is a luxury - success and failure are obvious." Similar to the supply chain philosophy, the resources and information are the critical issues in performance measurement implementation in SMEs.

2.2.4. Performance Measurement and Performance Measures Selection

The structured methodologies for performance measurement system design make it easier to decide what they should be measuring, to decide how they are going to measure it, to collect the appropriate data, and to eliminate conflicts in their measurement system (Neely *et al*, 1996).

Recommendations to construct the performance measurement are proposed by Maskell (1989).

(1) The measures should be directly related to the firm's manufacturing strategy

(2) Non-financial measures should be adopted

(3) It should be recognised that measures vary between locations - one measure is not suitable for all department or sites

(4) It should be acknowledged that measures change as circumstances do

(5) The measures should be simple and easy to use

(6) The measures should provide fast feedback

(7) The measures should be designed so that they stimulate continuous improvement rather than simply monitor

There are a lot of discussions on the selection of performance measures. All measurement systems consist of a number of individual performance measures, and there are various ways in which these performance measures can be categorised (Neely *et al*, 1995). Neely *et al* (1995) discussed a selection of the most important measures relating to quality, time, cost, and flexibility. Beamon (1999) provides measures categorised into three performance types; resources, output, and flexibility. The example measures are shown in the Appendix.

Hoek (1998) argued that the position of players in the chain (supplier, manufacturer, wholesaler, service supplier) affects their contribution and relevant measures, the level of integration and the strategic approach may affects the relevance of measures. Hence, the performance measures and performance measurement system must be designed under the environment where the company belong to. Bowersox *et al* (2002) also pointed out the role of players in different position in the supply chain with five critical dimensions: cost, customer service, quality, productivity, and asset management. To aim the achievement of supply chain integration, leading firms have instituted a set of across-firm metrics such as inventory days of supply, inventory dwell time, cash-to-cash cycle time, and total supply chain cost. From their description on the supply chain performance measurement, the measurement is based on the aggregate of measures across all firms in the supply chain.

As examples of performance measures in supply chain context, four areas of measurements and performance measures in a report by Andersen Consulting, Cambridge University and Cardiff Business School, and Stewart (1995) are shown in Table 2.2.

To design performance measures, Neely *et al* (1997) summarised the recommendations with regard to the design of performance measures from various sources as seen in Table 2.3.

Table 2.2: Comparison of Four Areas of Measurements and Performance Measures

Andersen Consulting, Cambridge University and Cardiff Business School	Stewart (1995)
Supply chain quality - Incoming defects - Internal defect rate - Customer complaints Supply chain inventories - Stocks of major, high volume incoming parts - Inventories in assembly areas - Finished goods inventories - Stock turn ratios Time in the supply chain - Incoming parts frequency of delivery - Instruction time to assembly (hours before production starts) - Journey time to customer - Frequency of delivery to customer Scheduling - Time between firm supplier order and actual delivery - Variability of schedule to major supplier - Internal scheduling practice (% use of pull system) - Time between final firm order and shipment	Delivery performance - Delivery-to-request - Delivery-to-commit data - Order fill lead time Flexibility and responsiveness - Production flexibility - Re-plan cycle - Cumulative source/make cycle time Logistics cost - Total logistics cost - Order management costs Asset management - Inventory days of supply - Days of sale outstanding

Table 2.3: List of Recommendations for the Performance Measures Design

- Performance measures should be derived from strategy
- Performance measures should be simple to understand
- Performance measures should provide timely and accurate feedback
- Performance measures should be based on quantities that can be influenced, or controlled, by the user alone or in co-operation with others
- Performance measures should reflect the "business process" – i.e. both the supplier and customer should be involved in the definition of the measure
- Performance measures should relate to specific goals (targets)
- Performance measures should be relevant
- Performance measures should be part of a closed management loop
- Performance measures should be clearly defined
- Performance measures should have visual impact
- Performance measures should focus on improvement
- Performance measures should be consistent (in that they maintain their significance as time goes by)
- Performance measures should provide fast feedback
- Performance measures should have an explicit purpose
- Performance measures should be based on an explicitly defined formula and source of data
- Performance measures should employ ratios rather than absolute numbers
- Performance measures should use data which are automatically collected as part of a process whenever possible
- Performance measures should be reported in a simple consistent format
- Performance measures should be based on trends rather than snapshots
- Performance measures should provide information
- Performance measures should be precise – be exact about what is being measured
- Performance measures should be objective – not based on opinion
Source: Adopted from Neely *et al* (1997)

2.2.5. Performance Measures Selection in SMEs

There is a discussion on the performance measures selection in the case of SMEs. Because of the limited resources for the performance measurement in SMEs, Hvolby and Thorstenson (2000) suggested that SMEs should select only the most critical performance measures. The advantages of the limited number of performance measures are:

The limited number of performance measures

- helps to state priorities clearly and to focus efforts for improvements
- reduces the efforts involved in measuring and recording the performance indicators
- makes adverse behaviour less likely because such behaviours is easily detected since the aggregate result is less likely to be manipulated

2.3. Background of Thai Automotive Industry

As one of the most advanced automotive production bases, Detroit in the United States is referred to be the centre of the automotive industry since the major automotive companies and parts/components suppliers from the upstream of the automotive supply chain have their factories, the supporting industry surrounds the environment, the skilled workers are also available in the area, and also the R&D knowledge and experiences are transferred to universities' research institutes. As a whole, the automotive industry has been developed by all of those participants. On the other hand, Thailand, which is aiming to be the Detroit of Asia, also attracts major automotive companies and has capabilities to support the industry. Major large assembly companies have their production base in Thailand, the parts/components suppliers can supply enough to the assemblers, and the whole production capacity still have opportunities to increase the export to foreign countries. Now, the investments to the supporting industry and the fundamental structures were increased by the automotive manufacturers, and Thai owned automotive assemblers such as Thai Rung and Tigers started their business in Thailand. Now, Thailand is one of the main production bases of 1 ton pick-up trucks in the world.

Ministry of Industry formulated the Master Plan for Thailand's Industrial Development for each industrial sector including the automotive industry. Under the Master Plan, the action plans were set up for five years 1998-2002. Thailand Automotive Institute (TAI) was assigned to under take the Master Plan for Thai Automotive Industry to be in accordance with the ninth National Social and Economic Development Plan 2002-2006. In the Master Plan, the Vision 2011 is set to be

"Thailand is the automotive production base in Asia that adds value to the country with strong domestic supplier base" (TAI, 2002).

2.3.1. Brief History of Thai Automotive Industry

The brief history of Thai Automotive Industry is seen in several papers. "Automotive Industry Development in Thailand during the Last Decade," which was composed in the end of 1990's gives detailed descriptions. In addition to the description of decades of the end of 20 century, some additional descriptions are based on the other available papers.

The history of Thai Automotive Industry could be roughly divided to some phases; Simple Assembly Phase, First Phase of Localization, Second Phase of Localization, Rapid Growth Phase, Liberalisation Phase, Slow Down, and Recovery and Growth Phase.

- Simple Assembly Phase (1960-1970)

The automotive industry in Thailand started in the early 1960's. This phase is called Simple Assembly Phase which is between 1960 and 1970. The policy for investment promotion was revised, and many automotive manufacturers from US, Europe, and Japan were attracted. This policy revision encouraged the set up of new assembly plants as joint ventures between Thai and foreign companies. In this phase, the localization of automotive production was not successful since only a few local parts such as Battery, Tires, and Spring Leafs are used for the assembly.

- First Phase of Localization (1971-1977)

The phase that began to move from the simple assembly of imported parts to the localization of automotive production was named First Phase of Localization. During this phase, the localization rate was introduced as 20% for passenger cars, 20% for pick-up chassis with windshield kits, and 15% for pick-up chassis with engine by January 1 1975. The investment for automotive parts production was boomed during the first half of the 1970's. During this phase, the production of automotive parts such as Brackets, Muffler, Wheel, Seat, Trim, Wire harness, or Rubber Parts were localized.

- Second Phase of Localization (1978-1986)

The phase that stricter measures were adopted to make the localization policy more effective is named Second Phase of Localization. In 1978, the establishment of new passenger car assembly plants was prohibited. In addition, the introduction of new series of passenger cars was prohibited, and this restriction was enforced for 12 years until 1990. With these restrictions, the restriction on the local content ratios was raised to 50% for passenger cars and to 45% for commercial vehicles in 1983. These local content ratios were revised upward and downward several times. The attention to pick-up truck production was changed. The strategic policy reemerged in 1985 was on the production of diesel engine with a specific focus on engines for 1 ton pick-up trucks. To response to this policy, four Japanese automotive manufacturers, Toyota, Nissan, Isuzu, and Mitsubishi set up engine plants in Thailand. In this phase, casting and machining business showed significant progress. Improvement on iron casting, and precision and complex machining, which lead to the improvement on press die and mould making, enabled manufacturers to produce higher value-added parts. Some automotive parts such as Brake Drum, Floor pan, Radiator, Glasses, Alternator, or

Lamps were produced locally in this phase.

- Rapid Growth Phase (1987-1990)

Following the economic recovery in 1987, the period between 1987 and 1990 achieved the rapid economic growth at double digit rates. The restriction on the new assembly plants resulted in the supply shortages although the purchasing power grew quickly following the domestic product growth. This demand growth made automotive companies realise that the locally produced automotive parts and components. The automotive manufacturers own their subcontractors set up supply lines in Thailand in order to take advantages of more cost effective labour, short delivery time, and closer access to suppliers. This demand lead to the second investment boom in the latter half of the 1980's as many Japanese automotive parts manufacturers invest in Thailand. During this period, automotive parts such as Engine component, Belts, Water & Oil pump, Piston, Valve, Body Part, Door, Trunk, or Bumper are manufactured in Thailand.

- Liberalisation Phase (1990's)

The automotive industry was liberalised drastically in 1990's in order to improve automotive assemblers' efficiency, technology and quality. The local content requirements on passenger cars were abolished in 1998. However, the requirements of pick-up trucks and commercial cars were remain in place until 2000. The Board of Investment (BOI), is the principal agency promoting the foreign direct investment into Thailand. The BOI is continuously offering the investment promotion to the automotive industry in the several categories.

- Slow Down (1997-1998)

The economic slow down significantly influenced the automotive industry as well. The sales and the production declined.

- Recovery and Growth (1999-present)

After the significant slow down, the automotive industry has been recovering gradually.

2.3.2. Car Production and Sales in Thailand

It should be noted that the automotive market in Thailand has quite unique characteristics with high proportion of pick-up trucks which is about 50-60% of the local market share. Thailand is the second largest pick-up truck market in 1996 after the biggest market in US.

Thai Automotive industry suffered heavy decline due to economic crisis in 1997 in terms of production and sales as seen in the Table 2.4 and 2.5 and Figure 2.7 and 2.8. However, the production and the sales have been recovering from the significant depression just after the bottom line in the year 1998. In year 2004, it is also expected that both of the production and the sales exceed the record in the year 2003 since the available data is recorded from January to August.

The importance of 1 ton pick-up trucks can be seen clearly in production share and the domestic market share in Thailand. Once focusing on the portion of the car types, passenger cars, 1 ton pick-up trucks and others, it is obvious that the 1 ton pick-up trucks donate the largest share in both the production and sales since long time ago. In year 2004, 1 ton pick-up truck production shared 40% of total car production and the domestic sales shared 59% of total car sales units compared to passenger cars' 32-33% in both statistics. These figures reveal how important 1 ton pick-up trucks' production and sales are in Thailand. Thailand is expected to be the one of the most important 1 ton pick-up trucks production base from now on as seen that Toyota and Isuzu moved their production into Thailand.

Table 2.4: Car Production in Thailand (TAIA)

Year	1999	2000	2001	2002	2003	2004*
1 Ton Pick-Up	240,369	294,834	289,349	229,000	302,914	237,506
Passenger Car	72,716	97,129	156,066	169,321	251,684	200,579
Total	327,233	411,721	459,418	584,951	750,512	584,394
% of 1 Ton Pick-Up	73.5	71.6	63.0	39.1	40.4	40.6

Table 2.5: Car Sales in Thailand (TAIA)

Year	1999	2000	2001	2002	2003	2004*
1 Ton Pick-Up	129,904	151,703	168,639	241,266	309,144	221,950
Passenger Car	66,858	83,106	104,502	126,353	179,005	135,622
Total	218,330	262,189	296,985	409,362	533,176	387,800
% of 1 Ton Pick-Up	59.5	57.9	56.8	58.9	58.0	57.2

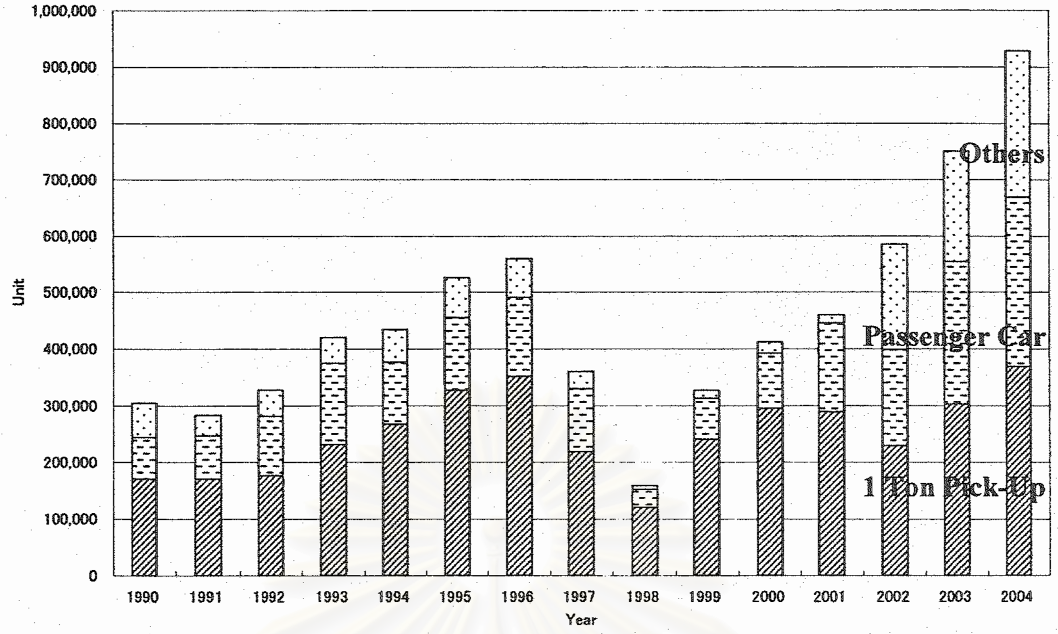


Figure 2.7: Car Production in Thailand since 1990 (TAIA)

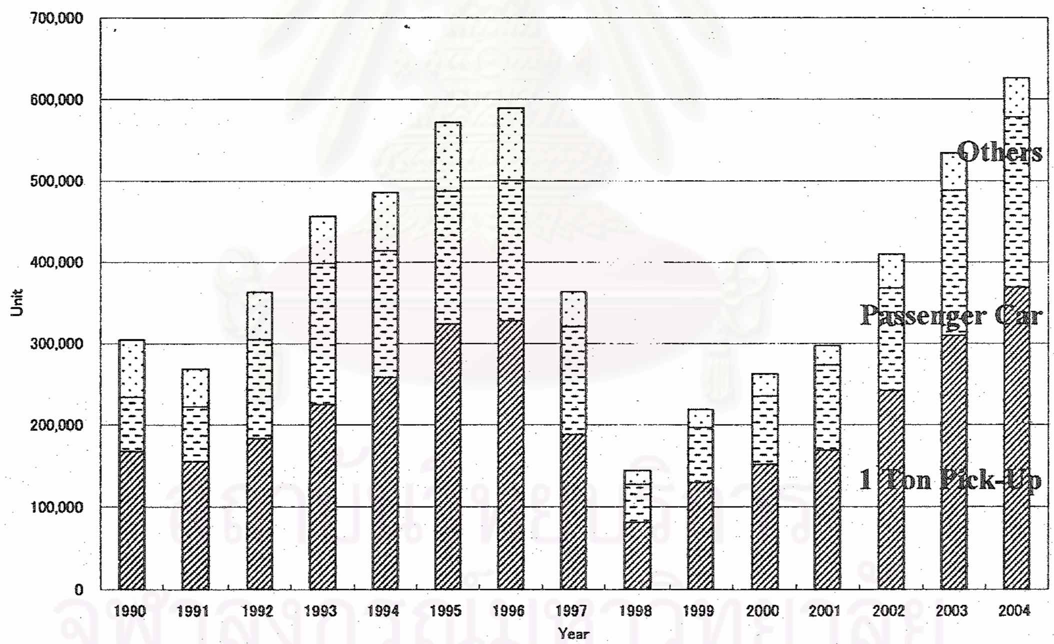


Figure 2.8: Car Sales in Thailand since 1990 (TAIA)

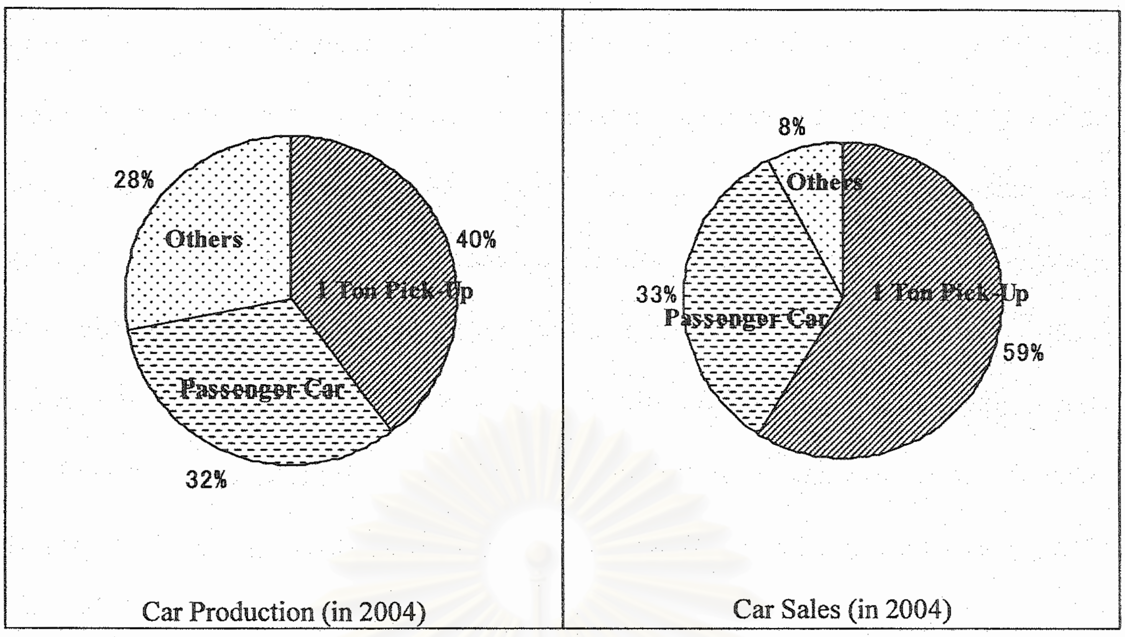


Figure 2.9: Shares of Car Production (Left) and Car Sales (Right) in Thailand (TAIA)

2.3.3. Issues and Supporting Activities

Although the growth of the automotive industry is rapid and the future vision is determined, some issues are foreseen. A study conducted by the Office of the National Economic and Social Development Board (NESDB), the Sasin Graduate Institute for Business Administration of Chulalongkorn University, and Prof. Michael E. Porter of Harvard University (2003) pointed out two critical issues in the Thai automotive industry; firstly, "the local expansion and relocation decisions of multinational automotive companies" depends on "the size and outlook of the domestic and neighbouring markets" and "the quality of the business environment such as the suppliers, workforce, and supporting industries' availability", and secondly, "the local suppliers' competitiveness" which include "low levels of productivity", "lack of capability to produce high precision, and complex parts," and "weak upstream supporting industries such as tools and machinery, mold and die, and steel." The relocation issues of the production bases are also pointed out by the explanation of the emergence of China and other ASEAN countries (Sussangkarn, 2004). The competitive issues are also reported by several researchers; especially, mold and die sectors often appear in the several reports. Tsunekawa (1998) mentioned that some high precision molds need to be procured from local Japanese producers or imported from abroad to manufacture the export products although locally produced molds or castings or forgings are used for local market. Although the Small and Medium sized Enterprises (SMEs) dominate the biggest portion in terms of the number of companies (Limskul, 1998), the value-added counts less than 20 per cent of value-added in the manufacturing sectors (Dhanani and Scholtès, 2002). As an example summary of advantages and issues, unpublished paper by TAI (2002) gave SWOT analysis of Thai automotive industry in Table 2.6.

Table 2.6: SWOT Analysis of Thai Automotive Industry (TAI, 2002)

Strengths	Weaknesses
- Production capacity available - Multi National OEMs - Political Stable and Democracy - Centralized Geography - Variety supporting industries in region - Good skill labors - Second largest global pick-up truck production - Good environment to do business for multinational company - Domestic market	- Shortage of capable Human Resource and lack of Knowledge - Education system is not suitable - Poor IT fundamental - No R&D Infrastructure - Testing laboratory is not sufficient - Not applicable technical regulation - Government regulation is not clear - Too high tax structure for Automobile - Financial crisis
Opportunities	**Threats**
- Global Auto Manufacturer choose Thailand to be regional production base - AFTA enables bigger market - Market expanding by bilateral FTA - Asia Pacific market have appealing future prospects - Potentially low-cost generic R&D - Create a niche segment market	- Foreign Investment in the region moves to China - Export from China to ASEAN - Great potential for low cost products from China and India - AFTA delay (Malaysia) - AFTA - Global structure excess capacity

To support problems seen in the Thai automotive industry, the skill developments are suggested (NESDB, 2003) and some programmes are undergoing (Itoga, 1998, Tsunekawa, 1998). Since the 1990's, Board of Investment (BOI) started to set up the promotion to develop technological skills in the prior basis. The first set of the promotion was determined to the Molds & Dies, Jigs & Fixtures, Casting, and Forging in 1993, and some segments such as Toolings, Surface Treatment, or Heat Treatment are added to the promotion in 1994, and other segments follows in the following years. The linkages between companies in the automotive industry are also encouraged by BOI Unit for Industry Linkage Development Plan (BUILD), which would lead to the cluster development and the competitiveness improvement. The linkages and supporting activities are not limited within companies in Thailand, and some organisations such as the Japan External Trade Organisation (JETRO) or Japan International Cooperation Agency (JICA) from Japan organise some supporting programs to enhance the technological skills in Thailand.

CHAPTER 3

DEVELOPMENT OF A SUPPLY CHAIN PERFORMANCE MEASUREMENT PROCESS

This section attempts to develop a comprehensive, but "easy to use" and suitable supply chain performance measurement process in Thai automotive industry, based on the previous literature reviews such as supply chain concepts, existing performance measurements, the background of the industry. The lower tiers of supply chain mostly dominated by SMEs are focused because it is considered that the awareness of performance measurement in supply chain context is required to improve the automotive supply chain.

3.1. Performance Measures Classification and Performance Measurement Matrix

The Balanced Scorecard (Kaplan and Norton, 1992) separates the performance measures into four areas; Financial, Internal, Customer, and Innovation perspectives. Financial perspective is probably the most important area to do their business, and the measures cannot be lacked in the performance measurement. Non-financial measures which were recommended to be included by Maskell (1989) were the other areas' measures. Those measures are necessary to improve their internal and external performances. However, the Balanced Scorecard is not balanced in supply chain context which emphasises not only the downstream but also the upstream activities as seen in Figure 3.1.

In the rest of this section, the ways to classify performance measures in supply chain environment are discussed. As the Balanced Scorecard shows, the performance measures should be balanced in a certain manner. The measures are divided into three different types of classifications: Responsible Process types, Measurement Area types, and Managerial Levels. The three classification types constitute the three-dimensional measurement classification, and this model is the foundation of the Performance Measurement Matrix.

3.1.1. Performance Measures Classification by Responsible Process Types

SCOR model successfully addressed the supply chain focus into four (five) processes: Plan, Source, Make, and Deliver (and Return). As seen in the Figure 3.1, the Source process focus on the supplier side and the Delivery process focus on the customer side. To balance the operations through the Source, Make and Deliver processes, the Plan process manage and support the information and materials flows. Although it seems that the SCOR model covers all the activities in supply chain, it doesn't describe or address some processes such as Sales and marketing, Training, Quality or Administration.

To compensate the lacked area in the SCOR model, another process or category is added so that other measures can be addressed. Once the financial perspectives shown in the Balanced Scorecard or the total performances are tried to put into the SCOR model, it is obviously difficult to do so. For example, where can Return on Investment (ROI)? ROI can be categorised into the Plan process, but it seems to be too much to do so because ROI is aggregate result by all activities in the firm. To support the lacked category in the SCOR, another category Others is added. The five performance measurement process types are shown in the Table 3.1, and the example measures are seen in the Table 3.4 and Appendix.

One perspective of the framework focusing on the background of Thai automotive industry is that major issues in the industry such as quality, human resources, or IT fundamentals could be measured or categorised into Others which SCOR does not fully address in its framework.

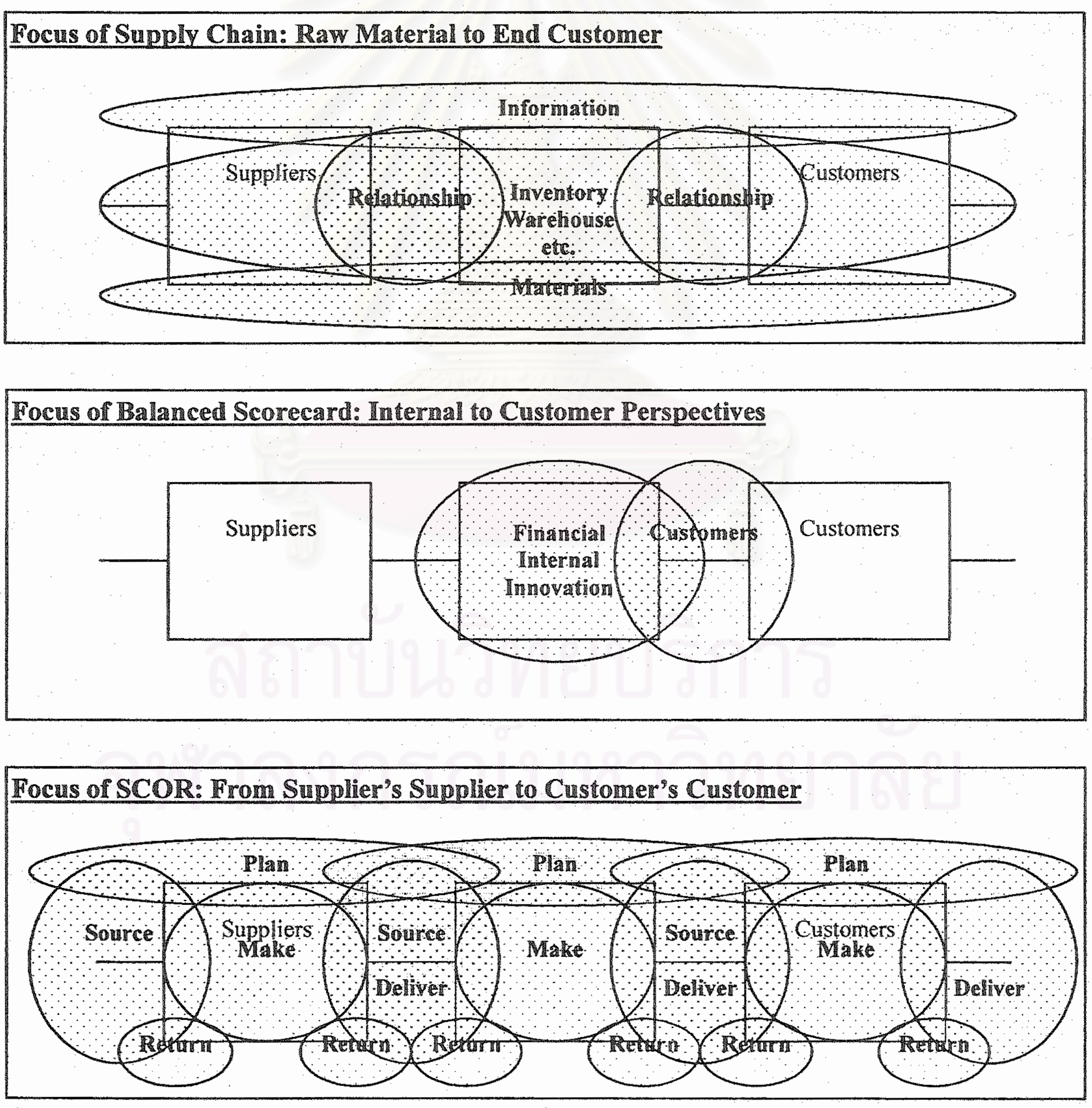


Figure 3.1: Focus Areas of Supply Chain, Balanced Scorecard, and SCOR

Although the process types from SCOR are adapted, the areas where each process covers are different as the Return process in SCOR which deals with raw materials return, finished goods returns, or other returns are included separately in other processes. For example, the defects return or claims from customers would be included in the Delivery process.

It also should be noticed that the responsible process types are set to assign the measurement to certain functional departments so that the measurements are conducted in company wide although the supply chain assumes less boundary between functional silos within and through the organisations. This approach, which is against the supply chain concepts, was introduced because the current practices in the industry can easily identify the measurement area and its responsibility for the measurement and because this approach may be a possible way to bring the industry the awareness of the supply chain concepts which deal with the wider view of management and the inter-company performances rather than the individual management or performance only.

Table 3.1: Five Responsible Process Types

Core Processes in SCOR model				Addition
Plan	**Source**	**Make**	**Deliver**	**Others**

3.1.2. Performance Measures Classification by Measurement Area Types

By adding another responsible process Others, any performance measures, which was not included in SCOR, can be addressed into either process category. However, as mentioned in the part of literature review, the SCOR model is complicated to adapt to the company that lacks resources. Also, SCOR model includes different types of performance measures in each core process. It would be necessary to classify the measures into measurement areas based on supply chain emphases so that the measures can be addressed based on the business objectives.

The measurement area that often appear in the literatures of supply chain are; Cost, Time, Inventory, Quality, Assets, Flexibility, Productivity, or Capacity Utilisation. These measures are identified in order to achieve the supply chain goals such as Cost reduction, Shorter manufacturing lead-time, Lower stock and inventory level, Cash flow improvement, Lower uncertainty risks, or Higher value to customers. The supply chain measurement studied by Andersen Consulting, Cambridge University and Cardiff Business School, and Stewart (1995) pointed out the four measurement areas as seen in Table 2.2. By eliminating the conflicts with previously described Responsible Process types such as Scheduling (=Plan) and Delivery, the four measurement area types are selected: Cost, Quality, Inventory, and Time. Then, they are renamed as four areas: Cost/Financial, Quality/Accuracy, Inventory/Waiting, and Time/Flexibility by matching similar measure terminology so that some measures can be easily addressed. The four measurement area types are summarised in the Table 3.2, and the example measures are seen in the Table 3.4 and Appendix.

It should be noticed that some measures can be categorised into one or more categories. For example, On-Time Delivery can be a Time measure, but also can be Quality measure. It is possible to consider that this confusion happens because of the focus of decision makers. From the different point of view, the measure can be categorised by business objective or by the responsible process for the measure.

Table 3.2: Four Measurement Area Types

Measurement Area Types			
Cost / Financial	**Quality / Accuracy**	**Inventory / Waiting**	**Time / Flexibility**

3.1.3. Performance Measures Classification by Managerial Levels

Another issue to deal with performance measures is which level of management the measurement is conducted at.

Gunasekaran *et al* (2001 and 2004), in their supply chain performance measurement study, categorised the performance measures into three levels of operational levels; Strategic, Tactical, and Operational as mentioned in the literature review. Strategic level focuses on the wished events, operational level focuses on the planned events, and operational level focuses on the current events. Using the three managerial levels, the measure can be assigned to a managerial level where it is most appropriate. The operational levels are set as another dimension of measurement. The three managerial levels are shown in Table 3.3, and the example measures are seen in the Table 3.4 and Appendix.

Strategic level focuses on wished events. Measures at strategic level influence the top level management decisions, reflecting investigation of broad based policies, corporate financial plans, competitiveness and level of adherence to organisational goals. Example measures would be supplier-customer relationship, total supply chain cycle time, total cash flow time, etc.

Tactical level focuses on planned events. Measures at tactical level deal with resource allocation and measures performance against targets to be met in order to achieve results specified at the strategic level. Measurement of performance at this level provides valuable feedback on mid-level management decisions. Example measures would be effectiveness of master production schedule, accuracy of forecasting techniques, etc.

Operational level focuses on current events. Measurements and metrics at operational level require accurate data and assess the results of decisions of low level managers. Supervisors and workers are to set operational objectives that, if met, will lead to the achievement of tactical objectives. Example measures would be capacity utilization, defects rate, etc.

It should be noted that some measures could be categorised into one or more managerial levels when it is appropriate (Gunasekara *et al*, 2004). This trend is also seen in the other performance measure classifications as explained before.

Table 3.3: Three Managerial Levels

Managerial Levels		
Strategic	**Tactical**	**Operational**

3.1.4. Performance Measurement Matrix

Previously described three measurement areas, Responsible Process types, Performance Measures types and Managerial Levels, compose the three dimensional matrix shown in the Figure 3.2. At the different managerial levels, performance measures will be assigned to a frame where it the most appropriate according to the performance measures types and the responsible process.

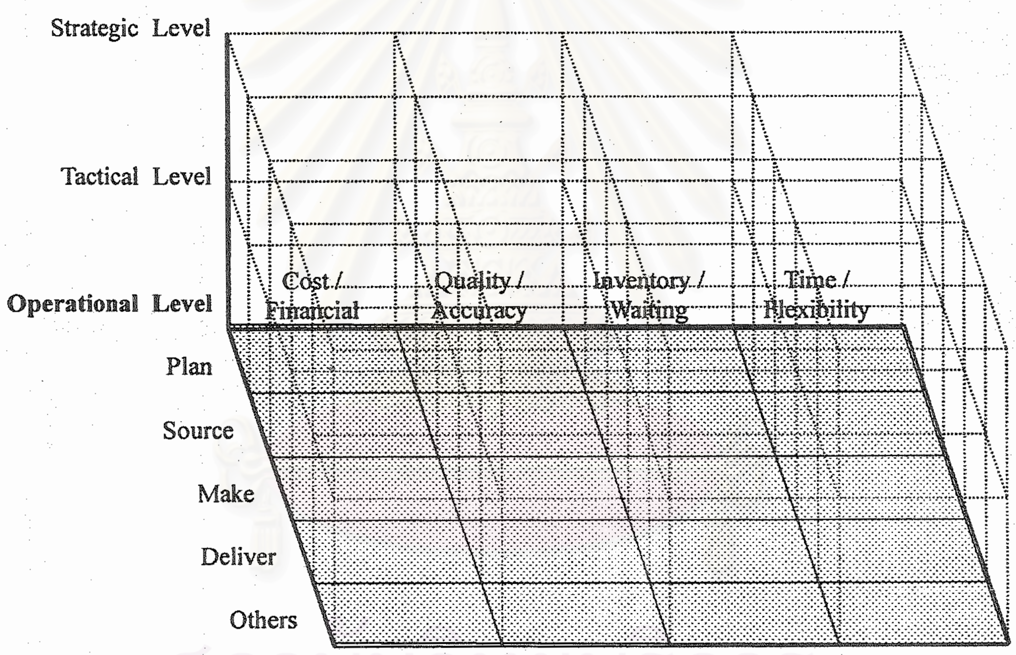


Figure 3.2: Three Dimensional Performance Measurement Types and Levels

The two dimensions of measurement areas, Responsible Process types and Measurement Area types, are used to construct the Performance Measurement Matrix at a managerial level. The performance measures can be addressed into the different supply chain process to identify the responsible process (or department) for the measurement, and into the different types to match the measures and the business objectives. The Table 3.4 gives the Performance Measurement Matrix and the examples of performance measures at operational level.

Table 3.4: Performance Measurement Matrix and Examples of Performance Measures at Operational Level

Operational Level		Measurement Area Types			
		Cost / Financial	**Quality / Accuracy**	**Inventory / Waiting**	**Time / Flexibility**
Responsible Process Types	**Plan** Information Flow and Planning	▪ Information Carrying Cost	▪ Forecast Cycle Time ▪ Data Entry Accuracy ▪ % of Data managed by information system ▪ Order Entry Method ▪ Effectiveness of master production schedule	▪ Customer query time ▪ Queued Data	▪ Order Response ▪ Cash Flow Time ▪ Scheduling Time ▪ Re-scheduling Time ▪ Total Cycle Time ▪ Order Lead Time ▪ Product development cycle time
	Source Inbound Logistics	▪ Raw Material Cost ▪ Raw Material Inventory as a % of Total Purchase	▪ Incoming Defects ▪ % of On-Time Delivery ▪ Number of shipping errors ▪ % of Defect Free Delivery ▪ Forecast Accuracy for Suppliers ▪ Number of return ▪ Mutual assistance in solving problems ▪ Mutual ability to respond to quality problems	▪ Incoming Inventory	▪ Raw Material Delivery Lead Time ▪ Frequency of Delivery ▪ Purchase order cycle time

	Make Manufacturing Operations	▪ Manufacturing Cost ▪ Work-in-Progress Turn ▪ Cost per operation hour	▪ Internal Defects ▪ Inspection Rate ▪ Productivity per head ▪ Number of Rework ▪ Scrap Level	▪ Work-in-Progress ▪ Machine Down Time ▪ Machine wait time ▪ Number of Stock-out	▪ Capacity Utilisation ▪ Machine Down Time ▪ Machine Wait Time ▪ Cycle Time ▪ Set-up Time ▪ Manufacturing Lead Time ▪ Range of products and services
	Deliver Outbound Logistics	▪ Distribution Cost ▪ Finished Goods Inventory Turn	▪ Claims from Customers ▪ % of On-Time Delivery ▪ Forecast Accuracy from Customers ▪ Number of shipping errors ▪ % of Defect Free Delivery ▪ Number of return ▪ Effectiveness of delivery invoice methods	▪ Finished Goods Inventory ▪ Inventory in transit	▪ Delivery Lead Time ▪ Average Lateness of Orders ▪ Average Earliness of Orders ▪ Time to Response Customer Inquiry ▪ Time to Response the Complaints ▪ Frequency of Delivery ▪ % of urgent delivery
	Others Others or Total	▪ Training cost ▪ Service Cost	▪ Skill Level ▪ Productivity ▪ Number of Improvement Idea ▪ % of Absenteeism	▪	▪ % of Late Comers

This framework intends to measure the performances in a firm and its suppliers and customers (Figure 3.3) by limited resources such as the limited internal information from the firm and external information from suppliers and customers. In the Performance Measurement Matrix at a managerial level, Source, Deliver or Plan processes should include the performance measures which can evaluate the linkage performances between suppliers and customers and the performances of suppliers and customers because those processes face to the upstream and downstream flows in the supply chain. Even in the Make or Others process, performances with suppliers and customers could be measured if there is cooperative activity in their operation. For example, the delivery performance from suppliers or the forecast accuracy from customers will be possible performance measures for the suppliers and customers in supply chain context. By measuring the external performances, it might be possible to see the stock levels at suppliers and customers, or the company can seek for the opportunities to improve the internal performances against the external performances, and the cooperative actions with suppliers and customers to improve wider scale of supply chain links.

This approach to the performance measurement within limited supply chain from the direct supplier to the direct customer would be the best and the widest focus in the discrete supply chain at the lower tiers of supply chain in Thai automotive industry. In order to introduce the basic supply chain concepts and its performance measurement, the minimum focus and the maximum results from the limited resources would be the most appropriate way to the further improvement of the supply chain.

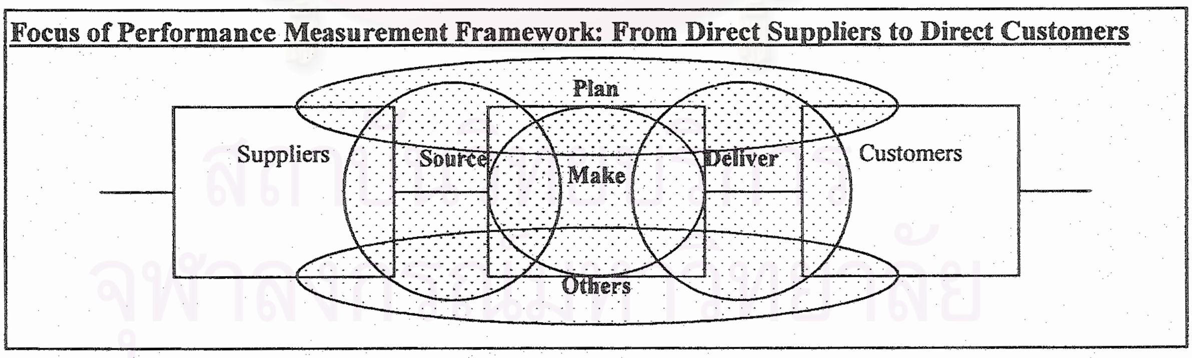


Figure 3.3: Focus Areas of Performance Measurement Matrix

3.2. Performance Measurement Template for Performance Improvement

As Kaplan and Norton (1992) and Neely *et al* (1997) gave performance measurement scorecard aiming the continuous improvement, a "Performance Measurement Template" is proposed. The template is not balanced itself as the Balanced Scorecard is. However, the template is used with the "Performance Measurement Matrix" to see what area they measure and how the measures are balanced in different areas.

The performance measure record sheet by Neely *et al* (1997) addressed the purpose, business objectives, target, responsible person, and what to do. In a new Performance Measurement Template addresses the responsible department in the measurement process from the Performance Measurement Matrix, and the latest result as well as the target and the result in order to see the progress and the possibility to achieve the target. An example of the Performance Measurement Template is shown in the Table 3.5.

Table 3.5: An Example of Performance Measurement Template

Process	Delivery
Responsible Department	Production Control
Measurement Area	Quality / Accuracy
Measure	Number of Defects found at Customer
Business Objectives	Improve Customer Satisfaction
Latest Result	2.1 % at July 2004
Target	0.5 % at the end of the year 2004
Result	2.0 % at August 2004
Formula for the Measure	Sum up the Claims on Defects
Source of Data	Claims from Customer
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the delivery results and investigate unexpected results
Notes	Current delivery performance is getting better by improved internal process. It is necessary to cooperate with QC/QA to improve the defects detection rate before shipping.

3.3. Guideline for Performance Measurement Process

As seen in the previous sections, Performance Measurement Process consists of two distinct processes; Performance Measurement Framework and Performance Measurement Template. Performance Measurement Framework helps users assign and balance performance measures into a cell based on responsible process and measurement area at a managerial level. Each performance measure in a Performance Measurement Matrix is recorded and used for the further performance improvement in a Performance Measurement Template.

For Performance Measurement Matrix, by asking which process and what kind of supply chain emphasis is represented in the matrix, the users may realise some importance of supply chain concepts. Some measures should be assigned to some aspects which the company may have not recognised before; it is considered that supply chain concepts are not emphasised in SMEs yet. Since the framework intends to measure a part of supply chain from the direct supplier to the direct customer, some measures especially in the Source and Deliver processes should include the performance measures of suppliers and customers. The performance measures should be balanced between business objectives and supply chain emphasis, and between Responsible Process and Measurement Area, and the number of measures should be limited so that the performance measurement can be easily implemented. The procedures and remarks to use Performance Measurement Process are summarised in the Table 3.6.

Table 3.6: Procedures and remarks to use the Performance Measurement Matrix

Procedures
1. Identify current problems based on business objectives
2. Select a managerial level where the measurement is conducted. (Section 3.1.3)
3. Select performance measures according to the identified problems. (Section 2.2.4)
4. Assign each performance measure into a cell in the Performance Measurement Matrix. (Section 3.1.1, 3.1.2 and 3.1.4)
5. Seek for other problems in supply chain contexts by asking which process and what kind of supply chain emphasis in the Performance Measurement Matrix are "not" focused at present. (Section 3.1.1, 3.1.2 and 3.1.4)
6. Assign performance measures, which are "not" focused before and found at the previous step, into a cell in the Performance Measurement Matrix. (Section 3.1.1, 3.1.2 and 3.1.4)
7. Balance the performance measures in the matrix based on the two dimensional measurement types. (Section 3.1.1, 3.1.2 and 3.1.4)
8. Limit the number of performance measures by balancing the identified and unidentified performance measures. (Section 2.2.5)
Remarks
1. Performance measures of suppliers and customers should be included in Source or Deliver processes (or other processes if appropriate). (Section 3.1.4)
2. New performance measures in supply chain emphasis, which are "not" focused before, should be included in the matrix.
3. Some measures could be categorised into multiple categories in the matrix; it may be required to be balanced with other measures based on business objective
4. Some recommendations from previous research should be referred as well. (Section 2.2.4)

For Performance Measurement Template, responsible department and manger, and the considerations and action plans should be addressed. The target setting for the improvement may require some considerations before the decision. Some measure may require individual target setting rather than total or average target setting. Target setting based on benchmarking may not be applicable to Thai automotive industry since it requires expensive data and the world class performance on those data may not be achievable target. To set an achievable target, consideration on historical performances or common sense for target setting may be adequate enough for the industry. The procedures and remarks to use Performance Measurement Template are summarised in the Table 3.7.

Table 3.6: Procedures and remarks to use the Performance Measurement Template

Procedures
1. Make a Performance Measurement Template for each performance measure in the Performance Measurement Matrix 2. Assign responsible department or manager for the measurement 3. Set the target for the improvement 4. Describe the considerations on the results and give action plans for further performance measurement and improvements
Remarks
1. Responsible department or manager could be multiple, collaborative approach may be required 2. Target may be given as the average figure when the continuous improvement trend can not be observed or the results fluctuates randomly 3. Target may be set for average for multiple items or for individual item depending on the measure's characteristics 4. Target should be achievable figure 5. Target may be set by historical performance and common sense

CHAPTER 4

A CASE STUDY: AN APPLICATION OF SUPPLY CHAIN PERFORMANCE MEASUREMENT PROCESS IN A SMALL THAI AUTOMOTIVE COMPANY

4.1. Background of the Case Company

The case company is a small Thai automotive company which is producing cast iron products for several customers. Products such as Fly Wheel, Drum Brake, Hub, or Pulley, which go through the casting process and the grinding process in the factory, are supplied to an automotive customer. This company give the first priority to this automotive customer by assigning 80 % production capacity of the factory. Since the direct automotive customer is a 2nd or 3rd tier of supplier of the automotive assemblers, this company position itself at 3rd or 4th tier of automotive supply chain (Figure 4.1). The roughly finished goods at the company are delivered to the customer to machine and finish the products to the next customer.

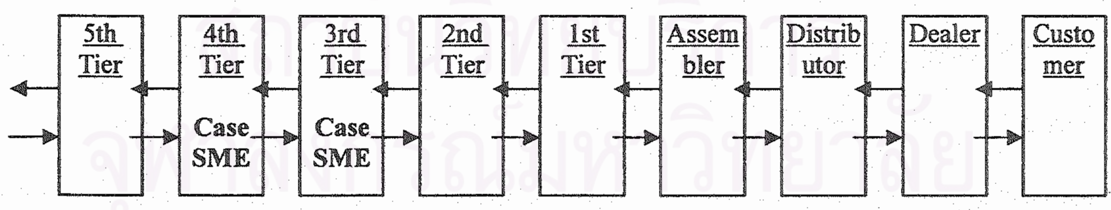


Figure 4.1: A Case Company's Position in the Automotive Supply Chain

The organisation of the company consists of about 80 employees. Most employees are assigned to the production department including Melting & Pouring, Mould Making or Grinding. The others are positioned as QC/QA, Maintenance, Drivers, Administration or Department Managers. The managers hold a post concurrently in different departments. Most of the decisions such as the production and delivery planning, purchase order, trouble solving are made by one General Manger. The organisational chart at present is given as Figure 4.2.

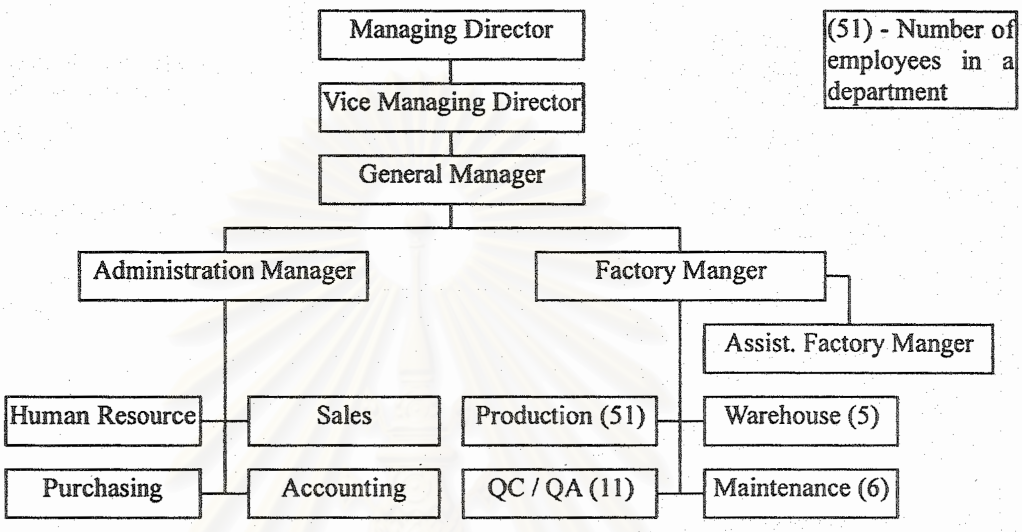


Figure 4.2: Organisational Chart in the Case Company

In this company, there are three major production processes; Mould Making, Metal Melting, and Finishing. At the Mould Making process, sand and some chemicals are mixed before the mould making by automatic mould making machine. At the mould making machine, a worker blow the mould surface to take off sand dust, check the surface, or put the core if necessary. At the Metal Melting process, steel scrap are melted and necessary amount of chemicals are added in the electric furnace before moving to ladle to pour the metal into the sand mould. After cooling the product inside of the sand mould, the product is taken off from the mould to cool, and the cooled products are sent to the Finishing process to grind and finish to delivery. At the grinding process, the sand sticking on the products are blasted, and workers grind the products on the grinding machine. The finished goods are kept on a pallet to deliver. The process flow chart is shown in the Figure 4.3.

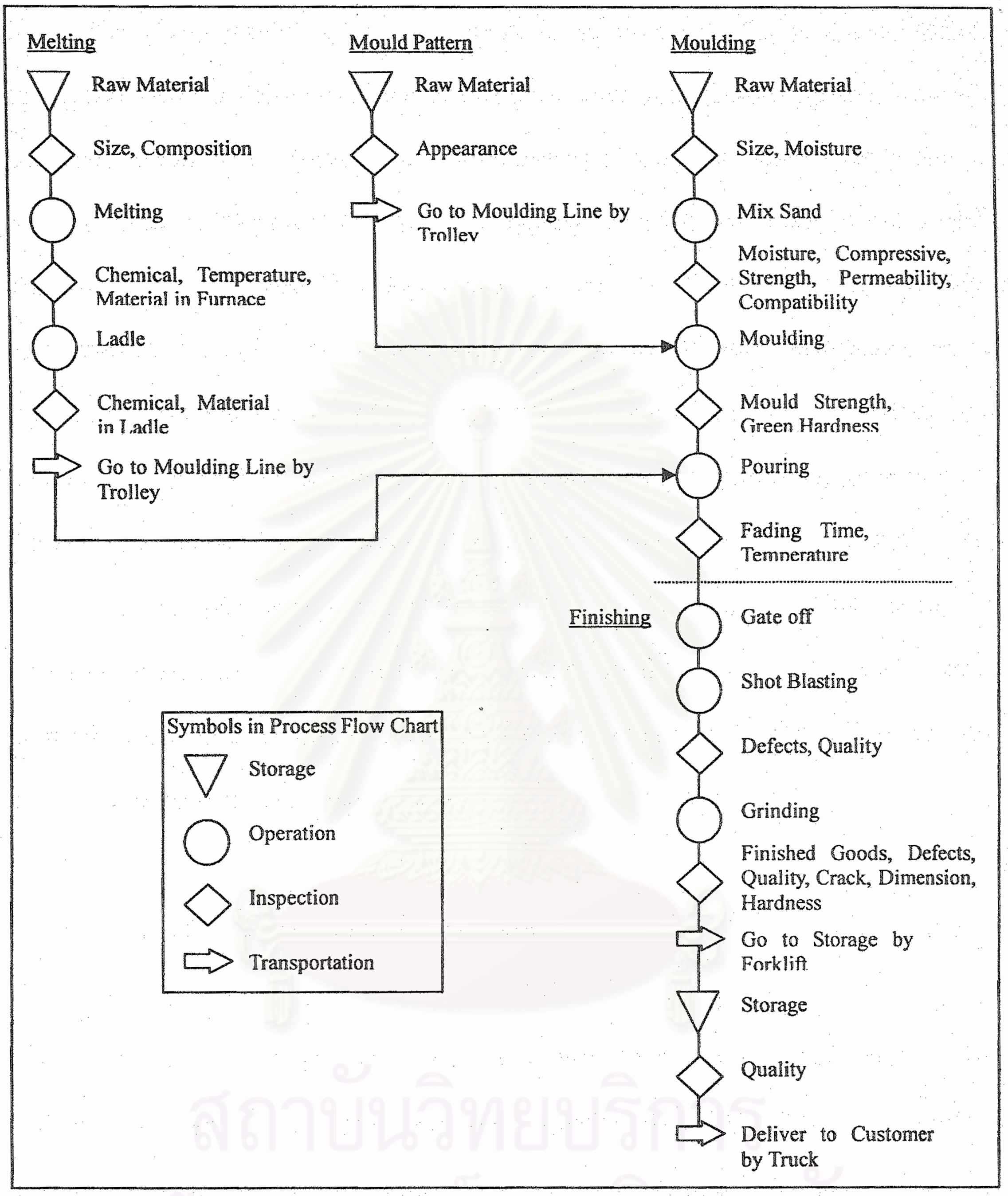


Figure 4.3: Process Flow Chart of Production Line

According to the initial interviews with managers, the company recognises some significant problems in the company at present. They have problems on product quality, human resources, inventory control, delivery performance, and etc, which are also the same problems as seen in Thai automotive industry. Firstly, the most significant issue is the product quality which derived from Machine or Workers from the company's point of view. The defects rate in the production line is at unacceptable level, and some defects are found at customer even after delivering the inspected products. Secondly, the turnover and absenteeism of workers causes other problems such as skill development or consistent quality. Thirdly, inventory is not strictly monitored by a responsible department, which caused stock-out or excessive inventory of raw materials and finished goods. Finally, delivery performance to the customer is not accurate. In the past, the customer required on-time (limited to a few hours) delivery at the first contract, but the policy was changed to any time in a day because the delivery performance was not good enough. During the initial data collection, the data entry errors were found. The data is managed by papers and electric format such as Excel data, but it seems that there is no a consistent rule or order for the data entry or data management. It is doubt that the data is just recorded but not measured for the improvements.

4.2. Performance Measures Selection

From the background of Thai automotive industry, the key issues in the industry are identified to be Productivity, Quality (NESDB, 2003), Value-Added (Dhanani and Scholtès, 2002), Human Resources, Knowledge or IT fundamental (TAI, 2002). In the other word, the industry wide issues are also the supply chain wide issues especially at the lower tiers of the supply chain where the SMEs dominate and the supply chain is not completely integrated. Hence the improvement on those issues could lead to the improved supply chain performance.

On the other hand, considering the unique characteristics of car production and sales in Thailand which has high proportion of Pick-Up Trucks, Percent of Pick-Up Trucks or Percent of Domestic and Export products could be success factors for the whole supply chain as well as the individual firm in the supply chain.

From the supply chain point of view, Thai automotive supply chain is not completely integrated at the lower tiers of suppliers (Figure 4.4). The automotive assemblers established the partially integrated supply chain within the group suppliers and dealers by the integrated information flow through the integrated information system. In this case, the assemblers have initiatives to control the chain by controlling the incoming components at assembly lines (needless to say, the demands from end customers control the production). At 3rd or 4th tiers of suppliers where mostly SMEs dominates and the case SME also positions, the supply chain seems to be discrete because of the lacked operational capability as seen as the issues in Thai automotive industry as well as the lacked resources such as IT fundamentals. However, the performances of SMEs are critical for the downstream activities especially in Quality of products because the improved product quality could reduce the defects, returns, or reworks at either supplier or customer. Delivery performance in terms of quality, quantity and time also could affect to the downstream activities. By improving the demand forecasting performance or communicating with suppliers and customers closer, the over production, over stock, or backorder could be reduced significantly.

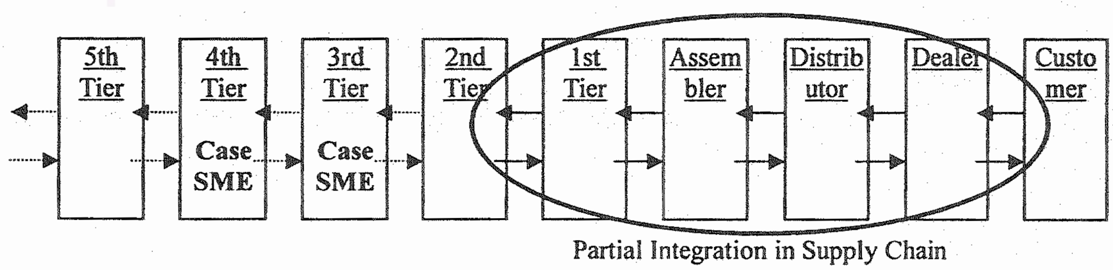


Figure 4.4: Partially Integrated Supply Chain

As explained in the previous section, the case company has some significant issues and gives priority to the improvement on quality, human resources, and inventory. Actually, the delivery performance is not considered to be significant issue because the customer and the company itself don't seriously care about the inventory level. However, from the supply chain point of view, the inventory level should be monitored.

Since these problems are mostly happening at the operational level, the measurement will be easily adopted by numerical data obtained in daily activities, and the improvement could impact on the company performance within the short period. The operational performance is also necessary for the supply chain integration at the strategic levels. Hence, it is considered that the performance measurement should focus on at the operational level as a first step of the performance improvement.

In Thai automotive industry which SMEs dominate in the majority in terms of the number of the organisations, it will be also useful to adapt the suggestions of Hvolby and Thorstenson (2000) which limit the number of measures to the critical performance measures in order to achieve the better results of performance measurement.

Based on the previous points, the performance measures measured in the project were decided as seen in the Table 4.1 and 4.2.

Table 4.1: Performance Measures in the case SME

Operational Level		Measurement Area Types			
		Cost / Financial	**Quality / Accuracy**	**Inventory / Waiting**	**Time / Flexibility**
Responsible Process Types	**Plan** Information Flow and Planning	▪	▪	▪ % of On-Time Delivery to Customer (P1)	▪
	Source Inbound Logistics	▪ Raw Material Inventory as a % of Total Purchase (S1)	▪	▪	▪ % of On-Time Delivery from Suppliers (S2)
	Make Manufacturing Operations	▪	▪ % of Internal Defects (M1)	▪	▪
	Deliver Outbound Logistics	▪	▪ Defects at Customer as a % of Total Delivery (D1)	▪	▪ Delivery Schedule Change from Customer (D2)
	Others Others or Total	▪	▪ Average Absence (O1)	▪	▪

Table 4.2: Description of Selected Measures

Measure ID and Name	Description
P1: % of On-Time Delivery to Customer	To measure delivery performance. The delivery can be earlier or should be on-time.
S1: Raw Material Inventory as a % of Total Purchase	To measure raw material inventory level. To monitor the inventory level. Fewer inventories are better. This measure can be used for the forecasting in the future.
S2: % of On-Time Delivery from Suppliers	To measure supplier delivery performance. The better the supplier delivery performance is, the fewer inventories can be kept in the company.
M1: % of Internal Defects	To measure internal defects level. One of the biggest problems in the company.
D1: Defects at Customer as a % of Total Delivery	To measure delivery quality level. Too much defects at customer increase the inspection at customer. Inspection performance in the company is also measured by this measure.
D2: Delivery Schedule Change from Customer	To measure customer's forecasting performance. The more consistent the forecast from customer is, the easier to schedule the production and delivery.
O1: Average Absence	To measure human resource performance. Too much absenteeism may lead to product quality level or productivity.

- P1: % of On-Time Delivery to Customer

This measure aims to measure delivery performance to customer. This measure is categorised into the Plan process and Inventory / Waiting type because the inventory, production and delivery planning capability effect to the delivery performance and the stock out happens. As a result, the back orders increases when another delivery schedule comes although the company is allowed to deliver earlier the delivery schedule. After achieving the zero back order, next step could be the less earlier deliveries.

- S1: Raw Material Inventory as a % of Total Purchase

This measure aims to measure raw material inventory level. This measure is categorised into the Source process and Cost / Financial type because the incoming stock level seems to rely on the supplier's decision on delivery, the stock levels fluctuate significantly, and the value of stock could effect to the financial performance. Since the supply chain intends to reduce the inventory through the chain, fewer inventories are better depending on safety stock level.

- S2: % of On-Time Delivery from Suppliers

This measure aims to measure supplier delivery performance. This measure is categorised into the Source process and Time / Flexibility type because the delivery from suppliers are not strictly monitored and the company rely on the suppliers' flexible response to their urgent order. This attitude may cause other significant issues such as excess stock or stock-out. The better the supplier delivery performance is, the fewer inventories can be kept in the company.

- M1: % of Internal Defects

This measure aims to measure internal defects level. This measure is categorised into the Make process and Quality / Accuracy type because the defects occurs in the production lines at the shop floor not anywhere else. Internal defect level is one of the biggest problems in the company as well as in the industry, and this level also could effect at defects at customer. Once the defects can be reduced, the downstream activities such as inspection or defects at machining process at customer could be reduced. As a result, the productivity at downstream supply chain could be increased by these reduced defects in this company.

- D1: Defects at Customer as a % of Total Delivery

This measure aims to measure delivery performance in terms of product quality. This measure is categorised into the Delivery process and Quality / Accuracy type because the internal defects should be detected before shipping to customer. Similar to the % of Internal Defects measure, this measure could effect at the customer's performance since too much defects at customer increase the inspection at customer. Inspection performance in the company is also measured by this measure.

- D2: Delivery Schedule Change from Customer

This measure aims to measure customer's forecasting performance. This measure is categorised into the Delivery process and Time / Flexibility type because the delivery schedule change make the company difficult to manage the production schedule and delivery schedule. By measuring the customer's forecasting performance, the company may act proactively to manage the uncertainty or improve their communication with customer. The more consistent the forecast from customer is, the easier to schedule the production and delivery, and the fewer the backorder could be.

- O1: Average Absence

This measure aims to measure human resource performance. This measure is categorised into the Others process and Quality / Accuracy type because the human resource performance could improve the productivity and product quality level. The performance of human resource is one of the biggest issues in the industry, hence in the supply chain. Improved attitude to the work could effect at the improved quality and productivity.

4.3. Investigated Results

- P1: % of On-time Delivery to Customer

To measure the company's delivery performance to the customer, % of On-time delivery to customer is measured, which is calculated as:

$$\text{\% of On - Time Delivery to Customer} = \frac{\text{Total Number of On - Time Delivery to Customer in a month}}{\text{Total Number of Scheduled Delivery to Customer in a month}} * 100(\%)$$

To measure the internal defects rate, five types of products are selected as the examples. They are Fly Wheel A, B and C, Hub B, Pulley E, and Ring F. These products have continuous demand, and the company recognises that the value is quite high. The calculated results are shown in the Table 4.3 and Figure 4.5.

The month 12 achieved the best delivery performance. However, in the most months, the on-time delivery counts less than 50% with the worst performance of 12.0%. The delivery performance by each product demonstrates around 30%. Low delivery performance is due to the stock out because the production cannot achieve the demand level. To achieve the higher delivery performance, the close relationship with planning and the production is the must.

Table 4.3: % of On-Time Delivery to Customer

	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
FW A	0.0%	14.3%	30.0%	40.0%	40.0%	9.1%	62.5%	11.1%	0.0%	62.5%	37.5%	100.0%	33.9%
FW B	14.3%	0.0%	52.4%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	55.6%	40.0%	100.0%	30.2%
FW C	-	77.8%	36.4%	0.0%	14.3%	0.0%	0.0%	33.3%	50.0%	33.3%	0.0%	0.0%	22.3%
HUB D	23.1%	0.0%	58.3%	0.0%	0.0%	52.0%	40.7%	27.3%	92.0%	63.2%	14.3%	25.0%	33.0%
PUL E	100.0%	0.0%	0.0%	36.4%	0.0%	0.0%	0.0%	0.0%	-	85.7%	75.0%	100.0%	36.1%
RING F	-	0.0%	100.0%	11.1%	33.3%	50.0%	33.3%	0.0%	0.0%	16.7%	50.0%	100.0%	35.9%
Ave.	34.3%	15.3%	46.2%	14.6%	14.6%	18.5%	22.8%	12.0%	48.4%	52.8%	36.1%	70.8%	

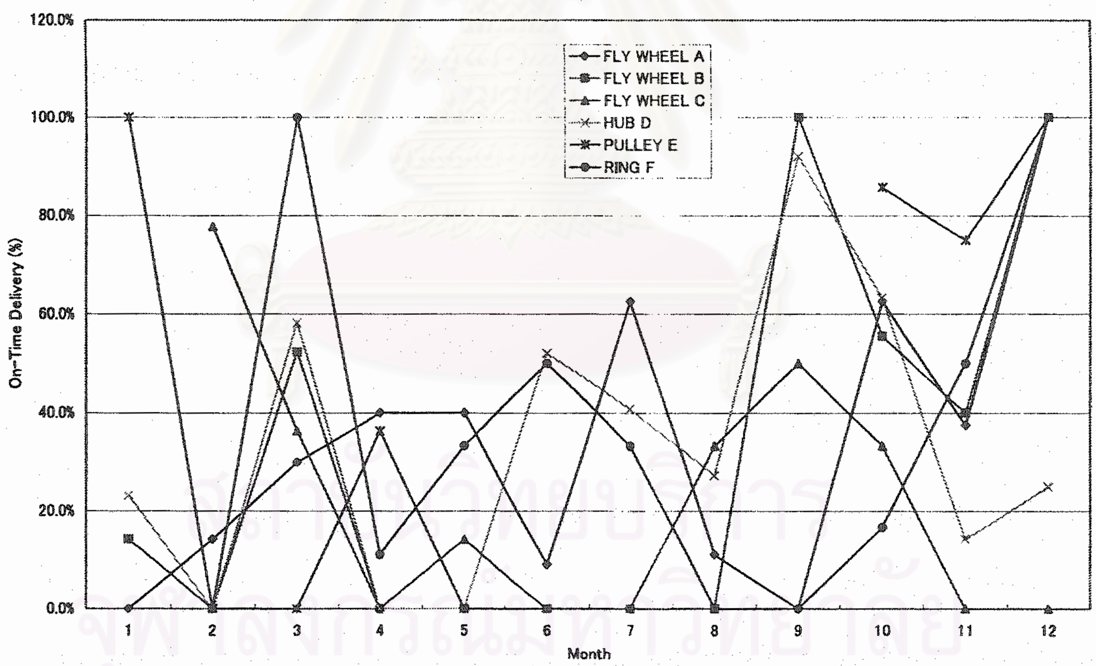


Figure 4.5: % of On-Time Delivery to Customer

- S1: Raw Material Inventory as a % of Total Purchase

To measure the raw material inventory level, some raw materials are selected by applying Pareto Analysis on value or inventory level of the direct raw materials for the automotive parts to recognise the raw materials' importance in the inventory. The importance of each raw material to produce a piece of product is the same since any raw material cannot be lacked to keep the product quality. However, the value of raw material can effect at the financial performance, and the too high inventory level is a waste in the company. Hence, the data of those examples are used to see the current raw material inventory level.

Raw Material Inventory as a % of Total Purchase is calculated by the following equation:

$$\text{Raw Material Inventory as a \% of Total Purchase} = \frac{\text{Raw Material Inventory at the end of month}}{\text{Total Purchase in a month}} * 100(\%)$$

After collecting the original historical data on the elements in the equation, the raw material inventory level is calculated for each example raw materials for a year. Table 4.4 shows the historical raw material inventory level with the averages against each product type.

Table 4.4: Raw Material Inventory Level as a % of Total Purchase in a year

RM No.	Raw Material Name	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
501-10	Silica Sand	17.0%	31.1%	9.3%	7.8%	7.2%	21.3%	9.4%	39.6%	13.2%	0.0%	26.6%	71.9%	21.2%
501-12	Bentonite	25.9%	38.8%	14.4%	13.3%	13.1%	3.6%	12.2%	4.9%	16.5%	23.7%	15.0%	25.0%	17.2%
501-14	Ferro Silicon	181.3%	77.9%	52.1%	83.3%	52.6%	36.2%	26.3%	0.0%	18.6%	10.0%	29.0%	35.5%	50.2%
501-15	Ferro Manganese	38.3%	87.7%	97.5%	-	71.0%	206.7%	-	-	66.7%	80.0%	-	-	92.6%
501-22	Steel Scrap	42.2%	18.3%	27.4%	33.1%	32.8%	43.0%	11.4%	10.0%	4.1%	8.0%	8.3%	7.9%	20.5%

Raw material inventory level 0.0%, for example, No.501-10 in month 10 means that the company used up the material. On the other hand, when the figures exceed 100%, for example, 181.3% of No.501-14 in month 1 or 206.7% No.501-15 in month 6, the material was unnecessarily purchased although there are a lot of inventory kept from the previous month. Some frames are empty because No.501-15, Ferro Manganese was not purchased in the month 4,7,8,11,12 although the inventory was kept.

Raw material inventory levels of some materials are kept around 20% as seen in the average figure as well as in the Figure 4.6. These materials are consumed quite frequently and quite a lot. The chemicals are also used for the production. However, the figures show that they have too high inventory level, which is not fairly managed.

The company considers that they need at least 3 days raw material inventories, which is about 10% of monthly demand. The reason why the company requires 3 days inventories is the delivery capability of suppliers which currently takes a few days to deliver in case the suppliers do not keep enough raw materials and cannot delivery responding to the order from the company. In the reality, the amount of consumption, the difficulty to purchase, the required period to deliver, or the suppliers' delivery performance would be different, as the shortage of scrap made the company change their purchasing practice or the problems in production line stops all the production and the raw materials deliveries are sometimes cancelled. However, the adequate inventory level for the company at present would be about 10%.

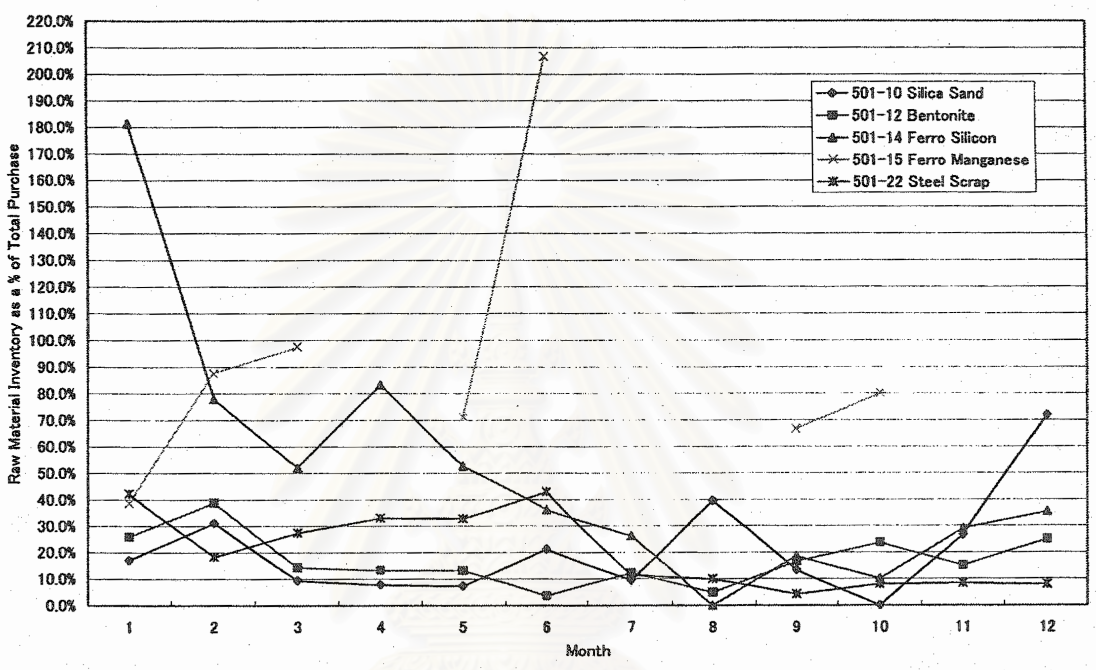


Figure 4.6: Raw Material Inventory Level as a % of Total Purchase in a year

- S2: On-Time Delivery as a % of Total Delivery from Suppliers

In the case company, the primary data on the deliveries from suppliers, such as Purchase Order or Delivery Receipt, are quite limited because some suppliers do not require the formal purchase order by documents and the delivery time/date is not strictly managed even though some of them are available in the original paper forms. To measure the suppliers' delivery performance, the primary data including the original paper forms and the secondary data including the interview with a manager are used.

Similar to the raw material inventory level, for the supplier delivery performance measurement, some raw materials delivered by some suppliers are selected by applying Pareto Analysis, and the same materials are used as examples. The interview on supplier delivery performance is limited to those selected raw materials, Silica Sand, Bentonite, Ferro Silica, Ferro Manganese, and Steel Scrap.

In the past, the company and the suppliers agreed on the delivery on specific dates, for example, one material from one supplier is delivered on Tuesday and Friday, and the supplier performed almost the perfect delivery within the company's delivery window. However, since after the company changed the policy on purchasing, the suppliers' performance also became worse because the company's order became more urgent than before; steel scrap suppliers are selected by price before the purchase order because the price rose due to the steel shortage in the world, and some orders were cancelled due to the worsen internal performance, which stops the production line. Even though the delivery performance form suppliers is a little bit worse than before, it takes only a few days to deliver the raw materials, which is not too significant issue to the company because the inventory level is not too low. In this sense, the suppliers can response to the company quite flexibly.

Although the original data is limited, the data obtained as original paper formats such as the Purchase Order with Delivery Schedule and the copy of Delivery Receipt shows that the supplier's delivery performance is good although the most of the purchase order is quite urgent as seen in the Table 4.5. This data also support the result of the interview.

Table 4.5: Examples of Delivery Schedule and Actual Delivery from Suppliers

RM. No.	RM Name	Supplier Name	P/O No.	Date of P/O	Delivery Schedule	Scheduled Amount	Actual Delivery	Actual Amount	On-Time/ Late(L)/Early(E)
501-10	Silica Sand	TCC	1165	9-Sep	9-Sep	1000	9-Sep	1000	On-Time
501-10	Silica Sand	TCC	1165	9-Sep	9-Sep	15000	9-Sep	15000	On-Time
501-10	Silica Sand	TCC	1169	9-Sep	16-Sep	15000	14-Sep	16000	2 Days (E)
501-10	Silica Sand	TCC	1165	9-Sep	23-Sep	15000	20-Sep	8000	3 Days (E)
501-10	Silica Sand	TCC	1191	5-Sep	5-Oct		5-Oct	16000	On-Time
501-10	Silica Sand	TCC	1191	5-Sep	9-Oct		8-Oct	16000	1 Day (E)
501-10	Silica Sand	TCC	1191	5-Sep	16-Oct		16-Oct	16000	On-Time
501-10	Silica Sand	TCC	1191	5-Sep	22-Oct		22-Oct	16000	On-Time
501-10	Silica Sand	TCC	1191	5-Sep	29-Oct		27-Oct	16000	2 Days (E)
501-22	Steel Scrap	CSS	0840	12-Jan	12-Jan		12-Jan	11330	On-Time
501-22	Steel Scrap	CSS	0850	13-Jan	13-Jan		13-Jan	11980	On-Time
501-22	Steel Scrap	CSS	0808	13-Jan	14-Jan		14-Jan	9770	On-Time
501-22	Steel Scrap	CSS	0809	14-Jan	15-Jan		15-Jan	10530	On-Time
501-22	Steel Scrap	CSS	0813	16-Jan	16-Jan		16-Jan	9070	On-Time
501-22	Steel Scrap	CSS	0820	17-Jan	17-Jan		17-Jan	9860	On-Time
501-22	Steel Scrap	CSS	0840	19-Jan	19-Jan		19-Jan	9240	On-Time
501-22	Steel Scrap	CSS	0840	19-Jan	19-Jan		19-Jan	8640	On-Time
501-22	Steel Scrap	CSS	0831	20-Jan	20-Jan		20-Jan	9050	On-Time
501-22	Steel Scrap	CSS	0832	21-Jan	21-Jan		21-Jan	9020	On-Time
501-22	Steel Scrap	CSS	0853	24-Jan	24-Jan		24-Jan	8660	On-Time
501-22	Steel Scrap	CSS	0842	26-Jan			26-Jan	15910	
501-22	Steel Scrap	CSS		26-Jan	27-Jan		27-Jan	9880	On-Time
501-22	Steel Scrap	CSS	0854	28-Jan	28-Jan		28-Jan	12000	On-Time
501-22	Steel Scrap	CSS					28-Jan	19380	
501-22	Steel Scrap	CSS	0858	30-Jan	30-Jan		30-Jan	15320	On-Time
501-22	Steel Scrap	CSS		30-Jan	31-Jan		31-Jan	15130	On-Time

The some raw materials such as Silica Sand and Steel Scrap are purchased and delivered frequently because such raw materials are used everyday. Such characteristics of raw materials may let the company allow its suppliers to deliver earlier, or even later, than the committed date of delivery.

- M1: % of Internal Defects

As same as the % of On-Time Delivery to Customer, to measure the internal defects rate, five types of products are selected as the examples. They are Fly Wheel A, B and C, Hub B, Pulley E, and Ring F.

% of Internal Defects is calculated as follows:

$$\%\text{ of Internal Defects} = \frac{\text{Total Number of Internal Defects in a month}}{\text{Total Number of Production in a month}} * 100(\%)$$

The results of calculation for example products are show in the Table 4.6 and Figure 4.7. Defects rate ranges from 0.0% to 77.1% across the products, and the average defects rate through the year range from 7.8% to 29.3%. These defects rate is completely far from the Parts Per Million (ppm) level.

In month 9 and 10, the internal defects rate significantly dropped from the other months although the defects come from different products for each month. However, the performance in the month 11 became worse again. The details should be analysed especially for this kind of situation to learn what was good or what was bad. The performance measurement will help this learning process.

Table 4.6: % of Internal Defects

	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
FW A	0.0%	14.0%	3.1%	22.8%	12.8%	30.9%	17.4%	8.2%	13.0%	0.0%	6.3%	62.8%	16.0%
FW B	15.1%	19.1%	23.3%	12.7%	26.0%	15.3%	18.9%	25.3%	1.0%	18.7%	29.2%	3.1%	17.3%
FW C	-	24.2%	17.5%	24.9%	8.8%	24.2%	25.1%	23.0%	12.9%	2.4%	17.5%	3.4%	16.7%
HUB D	21.8%	77.1%	26.1%	31.8%	39.8%	23.1%	40.6%	32.9%	11.8%	8.9%	31.3%	9.2%	29.5%
PUL E	12.9%	20.6%	47.1%	11.8%	17.7%	45.1%	60.2%	59.0%	6.3%	0.0%	10.7%	0.0%	24.3%
RING F	0.0%	24.2%	0.0%	11.4%	9.7%	0.0%	6.2%	11.4%	10.5%	0.0%	20.4%	0.0%	7.8%
Ave.	10.0%	29.8%	19.5%	19.2%	19.1%	23.1%	28.1%	26.6%	9.3%	5.0%	19.2%	13.1%	

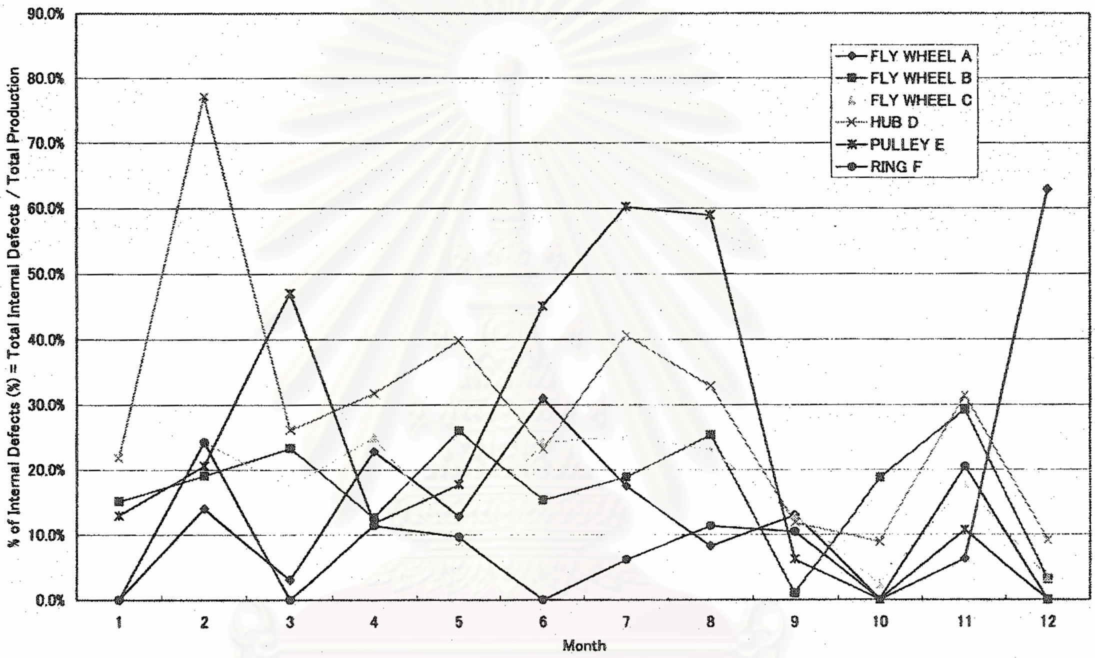


Figure 4.7: % of Internal Defects

- D1: Defects at Customer as a % of Total Delivery

Similar to the % of Internal Defects, Defects at Customer as a % of Total Delivery is measured. The equation is show as follows:

Defects at Customer as a % of Total Delivery

$$= \frac{\text{Total Number of Defects found at Customer in a month}}{\text{Total Number of Delivery in a month}} * 100(\%)$$

The defects at customer are reported as claim from customer. This means that the customer inspects the delivered goods even after the internal inspection at the company for shipment, and the defects rate at the customer is also not the ppm level. This result also suggests that the internal inspection is not performed successfully.

Table 4.7: Defects at Customer as a % of Total Delivery

	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
FW A	5.6%	4.5%	1.9%	2.8%	2.4%	7.6%	2.5%	2.4%	5.0%	1.7%	2.1%	25.7%	5.4%
FW B	2.9%	5.1%	8.7%	1.7%	5.2%	3.6%	3.4%	2.2%	1.8%	1.4%	3.4%	1.9%	3.4%
FW C	-	-	9.5%	7.9%	10.1%	4.8%	2.1%	2.1%	3.2%	5.0%	2.9%	3.9%	5.2%
HUB D	1.4%	17.4%	5.9%	2.2%	4.4%	2.7%	11.1%	1.4%	0.7%	15.5%	9.6%	11.2%	7.0%
PUL E	3.5%	0.6%	6.7%	1.0%	2.6%	0.9%	6.9%	13.5%	-	0.6%	0.0%	0.0%	3.3%
RING F	-	0.0%	0.0%	11.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Ave.	3.4%	5.8%	5.5%	4.5%	4.1%	3.3%	4.3%	3.6%	2.1%	4.0%	3.0%	7.1%	

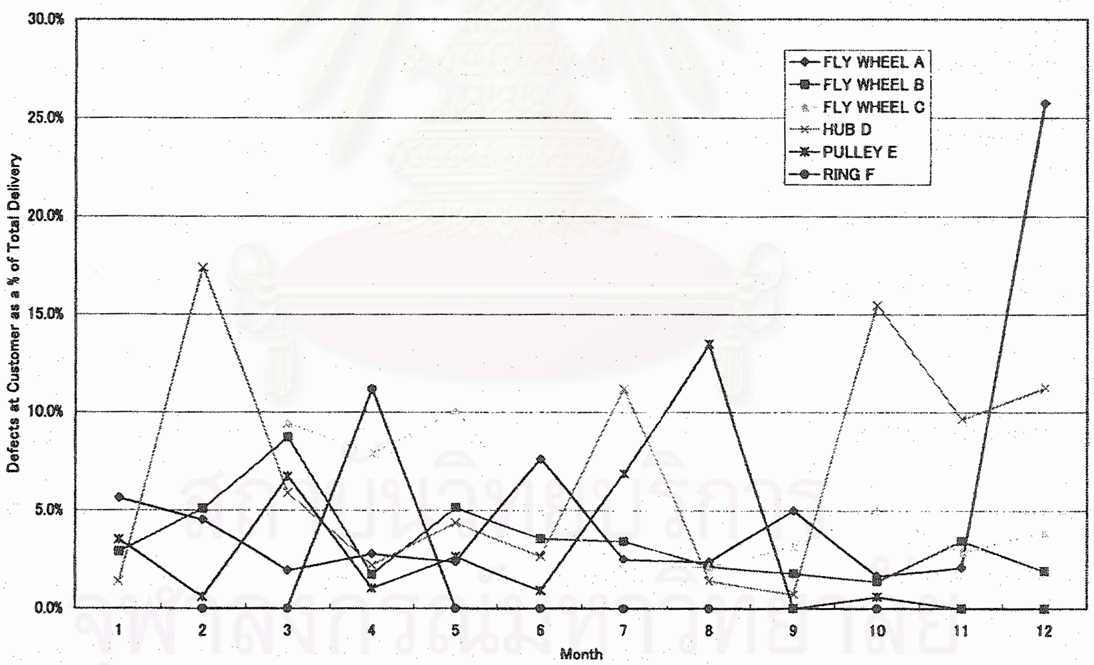


Figure 4.8: Defects at Customer as a % of Total Delivery

- D2: Delivery Schedule Change from Customer

Delivery schedule change from customer is considered to be a significant cause of lower production and delivery performance in the company.

Delivery Schedule Change from Customer is calculated as follows:

$$\text{Delivery Schedule Change from Customer} = \frac{\text{Increase/Decrease of Delivery Schedule in a month}}{\text{Delivery Schedule in a monthly schedule}} * 100(\%)$$

The delivery schedule is informed from the customer at the end of month for the next month. For example, the delivery schedule for December is informed at 29th November. The long-term forecast (for 3 month) is given by customer. However, the long-term forecast is not given sometimes. Hence, the company have to plan for the production and the delivery within a few days. Even after the monthly order, the delivery schedule is changed suddenly not periodically like weekly. Sometimes, the delivery schedule is changed within a few days after the monthly order. Moreover, it seems to be almost impossible to forecast the demand change since the demand change is significant ranging from small amount to more than 100% increase or almost 100% decrease as seen in Table 4.8 and Figure 4.9.

The customer's forecast performance is not reliable at all although the schedule was stable for several months in the past.

Table 4.8: Delivery Schedule Change from Customer

	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
FW A	-20.0%	-11.3%	0.0%	0.0%	0.0%	85.7%	0.0%	0.0%	0.0%	0.0%	-25.0%	-93.3%	-5.3%
FW B	40.0%	16.7%	0.0%	-6.1%	0.0%	-22.6%	0.0%	0.0%	0.0%	0.0%	0.0%	-53.3%	-2.1%
FW C	-	149.2%	0.0%	0.0%	0.0%	31.8%	0.0%	0.0%	0.0%	0.0%	0.0%	-2.5%	16.2%
HUB D	8.0%	1.5%	0.0%	0.0%	0.0%	13.6%	0.0%	0.0%	129.2%	0.0%	0.0%	-16.7%	11.3%
PUL E	-	31.4%	-28.6%	-45.0%	0.0%	4.8%	0.0%	0.0%	-	0.0%	0.0%	-7.3%	-5.0%
RING F	-	-	-80.0%	0.0%	-14.3%	18.4%	0.0%	0.0%	0.0%	0.0%	0.0%	-60.0%	-13.6%
Ave.	9.3%	37.5%	-18.1%	-8.5%	-2.4%	21.9%	0.0%	0.0%	25.8%	0.0%	-4.2%	-38.9%	

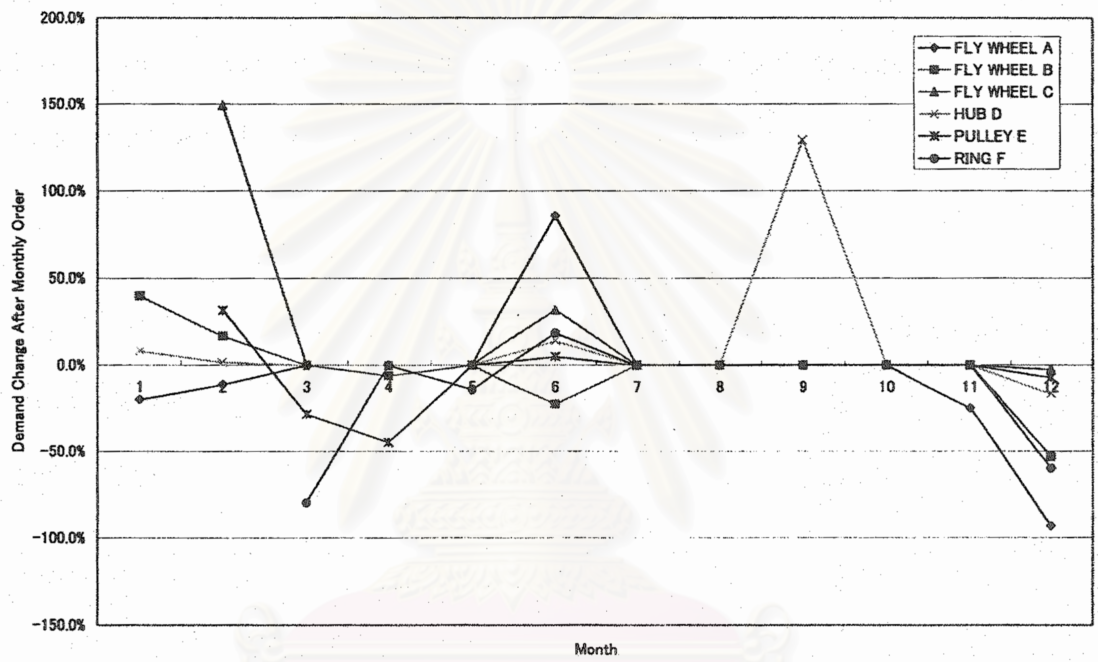


Figure 4.9: Delivery Schedule Change from Customer

- O1: Average Absence

Average absence is calculated against different functional department in a year. For example, average absence in a year means that an employee was absent except the company's normal holidays. According to a manager, some employees do not notice the absence. Hence, the actual absenteeism could be higher than the figures shown in the Table 4.9.

According to the results, QC/QA department has the highest average absence. And, it seems that the production related departments such as Furnace, Mould Making and Grinding have higher absenteeism than the other departments. Also, it may be suggested that the more employees are in a department, the higher the absenteeism is expected to be. Absenteeism could be a cause of lower productivity and lower quality leading to the high internal defects or high defects at customer measure. Hence, a solution for the improvements against internal defects and defects at customer may be achieved by improving the employees' attitude toward their work.

Table 4.9: Average Absenteeism

Functional Department	Number of Employee	Average Absence in a year in a department
Furnace (Melting)	12	11.0
Mould Making	8	14.1
Core Making	3	9.3
Grinding	28	13.4
QC/QA	11	17.5
Maintenance	5	8.9
Drivers for Delivery Truck, Forklift, and Bulldozer	5	9.2
Administrative Departments and Managers	7	8.9

4.4. Initial Performance Measurement Templates

The initial Performance Measurement Templates are also proposed for the case company to aim the further performance improvements.

The targets of the improvement especially for the defects rate and delivery performance are set as around half figure of the investigated historical results. Once the target to the half is achieved, the next target to the half could be achieved within the same period when the first target is achieved in a certain period (Maskell, 1991). The target is set as the average in a year because the figures are still fluctuating through the year and it is difficult to set an absolute figure for a measurement period. The managing director is involved in all the Performance Measurement Templates with his responsibility because he is currently managing those processes in the company. Some measures are assigned to several departments because the cooperative approach will be necessary through the department. Each Performance Measurement Template is show in the following Tables 4.10 to 4.16.

- P1: Performance Measurement Template for % of On-Time Delivery to Customer

The target for % of on-time delivery is set by 50% reduction of late delivery. Since the average % of on-time delivery was 30%, the late delivery was 70%. By reducing the late delivery to 35%, the target figure for on-time delivery is set as the 65% as average in the next year. It is suggested that the better scheduling and the internal defects reduction are also required to achieve this target. The template is shown in Table 4.10.

Table 4.10: Performance Measurement Template for % of On-Time Delivery to Customer

Process	Plan
Responsible Department	Managing Director
Measurement Area	Inventory / Waiting
Measure	% of On-Time Delivery to Customer
Business Objectives	Improve Customer Satisfaction
Latest Result	Average 70.8 % at Dec 2004 (Average around 30 % in Year 2004)
Target	Average 65 % in Year 2005
Result	
Formula for the Measure	Total Number of On-Time Delivery to Customer in a month / Total Number of Scheduled Delivery to Customer in a month
Source of Data	Scheduling Plan Sheet
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the delivery results and look for the improvement
Notes	Accurate and Achievable Scheduling and Lower Internal Defects are necessary. Closer communication and rearrangement for the delivery schedule to customer could be another solution for this issue.

- S1: Performance Measurement Template for Raw Material Inventory as a % of Total Purchase

The target for the inventory level is set as average 10% in a year for each material considering the suppliers' delivery performance which takes at least 3 days to delivery in case they do not keep the inventory. However, it should be noticed that the necessary inventory level would be different due to the amount of consumption, the period to delivery, or the suppliers' delivery performance would be different during certain period. For example, the steel scraps are difficult to purchase at present, so they may have to keep more inventory just in case. The template is shown in Table 4.11.

Table 4.11: Performance Measurement Template for Raw Material Inventory as a % of Total Purchase

Process	Source
Responsible Department	Managing Director / Purchasing
Measurement Area	Cost / Financial
Measure	Raw Material Inventory as a % of Total Purchase
Business Objectives	Balanced Inventory
Latest Result	RM-501-10, 71.9 % at Dec 2004 (Average 21.2 % in Year 2004) RM-501-12, 25.0 % at Dec 2004 (Average 17.2 % in Year 2004) RM-501-14, 35.5 % at Dec 2004 (Average 50.2 % in Year 2004) RM-501-15, 80.0 % at Oct 2004 (Average 92.6 % in Year 2004) RM-501-22, 7.9 % at Dec 2004 (Average 20.5 % in Year 2004)
Target	Average 10.0 % for each raw material in Year 2005
Result	
Formula for the Measure	Raw Material Inventory at the end of month / Total Purchase in a month
Source of Data	Balance Sheet of Inventory, Purchase and Used Raw Material
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the inventory level, eliminate the unnecessary purchase and reduce the excess inventory
Notes	It might be better to set an inventory controller in the factory who manages the inventory from raw material, work in process, to finished goods. At least, some unnecessary purchase and exceeded chemical inventory should be eliminated.

Table 4.12: Performance Measurement Template for % of On-Time Delivery from Suppliers

Process	Source
Responsible Department	Managing Director / Purchasing
Measurement Area	Time / Flexibility
Measure	% of On-Time Delivery from Suppliers
Business Objectives	Balanced Inventory
Latest Result	Approximately 100 % in Year 2004
Target	100 % in Year 2005
Result	
Formula for the Measure	Total Number of On-Time Delivery from Suppliers in a month / Total Number of Scheduled Delivery from Suppliers in a month
Source of Data	Purchase Order with Delivery Schedule and Delivery Receipt
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the supplier's delivery against the committed delivery date
Notes	Even though the forecast from the company to suppliers is not offered, the suppliers manage and deliver the required raw material almost perfectly. To establish better relationship with suppliers to keep the internal inventory lower, the purchase forecast should be adapted.

- S2: Performance Measurement Template for % of On-Time Delivery from Suppliers

Most of the suppliers' deliveries are on-time at least earlier than the due date. Hence, the target as % of on-time delivery from suppliers is set as 100%. However, to reduce the uncertainty from supplier side and to control the inventory level in the company, they should improve the communication with suppliers based on the supply chain concepts. The template is shown in Table 4.12.

- M1: Performance Measurement Template for % of Internal Defects

The target is set as average 10% in a year by reducing the defects rate to half of 18.6% in the previous year. Although 10% is far away from the industry standard, it is considered that an achievable target should be provided. The template is shown in Table 4.13.

Table 4.13: Performance Measurement Template for % of Internal Defects

Process	Make
Responsible Department	Managing Director / Production / QC/QA
Measurement Area	Quality / Accuracy
Measure	% of Internal Defects
Business Objectives	Better Product Quality and Customer Satisfaction
Latest Result	Average 13.1 % at Dec 2004 (Average 18.6 % in Year 2004)
Target	Average 10 % in Year 2005
Result	
Formula for the Measure	Total Number of Internal Defects in a month / Total Number of Production in a month
Source of Data	Daily Production and Defects Report
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the defects rate and look for possible improvement
Notes	Product quality is the biggest concern in the company at present. There would be diversified solutions on this matter. Possible causes of this matter should be solved by not only pointing out them.

- Performance Measurement Template for Defects at Customer as a % of Total Delivery

The target is set as the halved figure of the previous year. There are many factors to reduce the defects at customer as seen in the previous section. The internal defects rate significantly affects this issue, or the high absenteeism at QC/QA department may also a possible cause of this issue. However, the performance of quality control is the most significant factor to improve this performance. The template is shown in Table 4.14.

Table 4.14: Performance Measurement Template for Defects at Customer as a % of Total Delivery

Process	Deliver
Responsible Department	Managing Director / Production / QC/QA
Measurement Area	Quality / Accuracy
Measure	Defects at Customer as a % of Total Delivery
Business Objectives	Better Product Quality and Customer Satisfaction
Latest Result	Average 5.4 % at Dec 2004 (Average 4.2 % in Year 2004)
Target	2 % in Year 2005
Result	
Formula for the Measure	Total Number of Defects found at Customer in a month / Total Number of Delivery in a month
Source of Data	Claims from Customer and Actual Delivery Record
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the claims
Notes	Cooperation with production and QC/QA. QA should guarantee the defects free delivery to the customer.

- Performance Measurement Template for Delivery Schedule Change from Customer

This is the most difficult performance to improve because it is the external performance at customer. However, it is considered that the better communication with customer will influence their performance on delivery schedule change. Since the products are outsourced to the company because the demand exceeds customer's production capacity, the delivery schedule is planned according to the order from customer's customer. If the demand from customer's customer could be opened to the company, the delivery schedule or production schedule could be planned properly. Based on the delivery schedule change through the previous year, the target is set as less than 10% fluctuation through the year. The template is shown in Table 4.15.

Table 4.15: Performance Measurement Template for Delivery Schedule Change from Customer

Process	Deliver
Responsible Department	Managing Director / Sales
Measurement Area	Time / Flexibility
Measure	Delivery Schedule Change from Customer
Business Objectives	Better Delivery Performance and Customer Satisfaction
Latest Result	From -2.5 % to -93.3 % at Dec 2004 (From -93.3 % to 149.0 % in Year 2004)
Target	From -10 % to 10 % in Year 2005
Result	
Formula for the Measure	Increase/Decrease of Delivery Schedule in a month / Delivery Schedule in a monthly schedule
Source of Data	Delivery Schedule from Customer
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the delivery schedule change
Notes	It is difficult to manage the delivery schedule from customer at operational level, since it is an external measure. However, the sales force may get closer to the customer to get the forecast or demand of customer's customer directly.

- Performance Measurement Template for Average Absence

The target is set as 10 days absence of average per employee in a year although t is difficult to state the adequate absence. However, by monitoring the absenteeism in the company, the productivity, quality, skill development issues could be found. The employees' satisfaction at work place should be improved by certain ways to improve the outcome from them. The template is shown in Table 4.16.

Table 4.16: Performance Measurement Template for Average Absence

Process	Others
Responsible Department	Managing Director / Assist. Managing Director / Human Resource
Measurement Area	Quality / Accuracy
Measure	Average Absence
Business Objectives	Improve operations
Latest Result	12.6 Days per employee in Year 2004
Target	10 Days per employee in Year 2005
Result	
Formula for the Measure	Total Absence / Total Number of Employee in Department or Company
Source of Data	Absent Check
Frequency to measure	Monthly (collect data daily)
What/How do they do	Monitor the employee's absenteeism
Notes	The high absence in production line may be a cause of low product quality. As well as the customer satisfaction, the employee satisfaction may be considered.

4.5. Recommendations for the Case Company

During the investigation process, some recommendations are considered as an initial step to implement the performance measurement and to make easier to be implemented. Since the company is small, the resources information and capital are not enough. Although some information systems in the market could be a significant help to the company, it is assumed that the existing data management system mostly based on paper forms and Excel data is continuously utilised. Based on this assumption, several recommendations are presented. Some recommendations may require strategic approach especially in the partnerships with suppliers and customers.

(1) Set the consistent rules to manage the data

It was really confusing to analyse the data because the data is sorted by random sequences. This confusion might happen because the outsider of the company looked for the information. However, it seems for anyone to take time to find necessary data in the file. For example, the product or raw material name is not sorted by alphabetical order or the invoices or other original data are not filed by date.

Hence, the company should have the consistent rules to manage the data, for example, by alphabetical order or by date. By applying the consistent rules, the time wastes to find the necessary data or the data entry error will be significantly reduced. Furthermore, the data managed with consistent rules can lead to the easier data analysis for the performance measurement without keeping the data just as “record” but as “measure.”

(2) Manage the data with ID numbers

Similar to the previous point, and to support the consistent data management, the data should be labelled by certain ID numbers. For example, the varieties of about 70 raw materials including direct and indirect are newly labelled within a year according to the historical data on raw material inventories. It is probably because it was difficult to manage the plenty of data by looking for specific raw material in the inconsistently sorted list. However, the other data such as product names or employees are still sorted random sequences and not labelled. Products are newly introduced or terminated, or employees come in or go away from the company as time goes by. To make the data is easily recognised as different in a second, the data should be managed by ID numbers.

(3) Make the data available to anyone in the company

The most data can be accessible by any computer in the company. However, the data seems to be managed or categorised in several folders by each responsible person. Similar to the previous two recommendations, the data is managed inconsistently without any rules which could enable people recognise the data easily. Especially, the production and delivery scheduling data management relies on only the general manager's mind. It is suspected that any urgent response can be done especially on the scheduling if the manager is absent. It may be better for the company to share the data and to let anyone to understand what is happening in the company where the person is not directly responsible. Since the company is small and managed by few people, it could be done without big problems.

(4) Make use of the smallness of the company

Since the company is quite small with about 80 employees and less than 10 managers in the same office without any boundaries between departments, the communication between different departments are not limited. In the supply chain, the first thing to overcome could be the elimination of the boundaries between department and companies so that the each process can be managed through the supply chain. Although the smallness of the company has some obstacles such as limited resources, the small company have the high potential to be cross-functional, cross-learning and improvement. Hence, the advantage of the smallness should be reconsidered and enhanced.

(5) Never think the small company can do nothing

The initial interview was impressive since a manager said that small companies cannot achieve the world class performance or cannot be integrated into the supply chain because small companies do not have power against suppliers and customers. It sounds that the problems in the company derived from the smallness of the company. As explained in the previous point, the smallness is not just the weakness, but it has a potential for improvement which larger companies cannot do. There may be several ways for small companies can be superior to the larger companies.

(6) Communicate and negotiate with suppliers and customers

At present, the company rely on the suppliers for raw material delivery in terms of quantity and time, and on the customer for the demand. Suppliers estimate the company's demand and deliver the goods periodically. The automotive customer orders the products and changes the delivery schedule significantly in a month. As the manager said, the company may not have power in the current supply chain. However, the dependence to suppliers and customers seem to be the causes of problems such as unmanaged inventory level, low product quality, or low delivery performance. Supply chain management gives the company to look for the opportunities to improve their performance by managing and cooperating with the suppliers and customers. Hence, the relationship with suppliers and customers should be reconsidered as well as the improvement of scheduling.

(7) Make use of the data

What you measure is what you get. As seen in the initial data collection, the data is just a record not a measure. To analyse the existing data in the company is not an easy task because of its inconsistency and inconvenient for the general user. With the implementation of consistent rules and ID number for the data management, it should be kept in mind that the data is not just a record but a source of measurement for performance improvement.

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

5.1. Conclusions

In this paper, a supply chain performance measurement process in Thai automotive industry is proposed. It is developed based on previous performance measurement research by different area such as performance measurement in general, performance measurement in supply chain environment, or performance measurement in SMEs. The Performance Measurement Matrix intended to measure different areas in Responsible Process types (based on SCOR), Measurement Area types (based on supply chain focus), and Managerial Levels. Some considerations on issues in Thai automotive industry such as productivity, quality, human resource, and IT fundamental are addressed in the framework by adding Others process which SCOR does not clearly addressed. The Performance Measurement Template is proposed as an initial step for the further performance improvement by representing the target as well as the latest result. Overall, Performance Measurement Process is developed to help SME users, which may lacks resources, to understand the supply chain focus and address performance measures easily for the further performance improvements by categorising the measurement areas based on the supply chain process and focus.

The focus of the process is limited to a part of the whole supply chain; from the direct customer to the direct customer. To measure the performance of the limited supply chain, the available data from suppliers and customers such as the delivery record of raw material from suppliers or the delivery schedule from customer is utilised. From the limited resources and interview, the current activities are understood and the opportunities for the improved supply chain are recognised.

The process is tested at the operational level for some reasons: the immediate impacts on improvement can be expected; the data is easily collected from the daily activities; and the problems such as quality, productivity, or human resource in the company and the industry seem to be happening at the operational level.

As the interview acknowledged, the data shows the problems on delivery performance, inventory level, product quality, and human resource. One measure on suppliers' delivery performance shows a high performance even though the company's capability on forecasting and scheduling are not sufficient. There are a lot of opportunities for improvements in the product quality and delivery performance by managing and improving the internal processes with better scheduling techniques not depending on a manager's experience and sense. There is also necessity on supplier and customer relationships so that the inventory and demand can be managed through the limited supply chain and the wider supply chain in the future.

When assigning the measures in the framework, it is found that the Responsible Process types which is based on SCOR can be useful for the company to see balanced approach for the each supply chain functions from supplier to customer or incoming logistics to outbound logistics. As foreseen in the development phase, there were some difficulties on assigning measures to the Measurement Area because of the company's business focus heavily on the quality improvement rather than the inventory level or the timeliness of the activities. However, considering the

Measurement Area type can give the company the importance of the inventory and the timeliness in the supply chain, some measures are assigned to the inventory level and delivery performance. Therefore, the Performance Measurement Process will give the understanding and awareness to the supply chain management to the users by intending to balance the measures on the framework and asking what measure is important in what measurement area at which process, why the measure is important for supply chain, who in which process is responsible for the measure, and how to improve the measure.

The proposed supply chain performance measurement process was applied to a small automotive company assuming that the company is a typical company in Thai automotive industry. Therefore, it is expected that this supply chain performance measurement process can be applied to the other companies in the industry. However, it seems to be difficult to conclude that this framework can be applied to the other supply chains in the other industries although the proposed performance measurement process is generic.

It is hoped that the supply chain performance measurement process can give the companies especially SMEs in Thai automotive industry the awareness of supply chain concept and the first step to the internal and the supply chain performance improvement.

5.2. Recommendations for Further Research

There are several recommendations for the further research.

(1) Change measures according to the performance improvement

The performance measures can be and should be changed based on the improvement.

(2) Measurement on the different managerial levels

The scope of the performance measurement in the case company was limited to the operational level to obtain the recorded numerical data based on daily activities and to expect the immediate impacts on the improvement. When the performances at the other levels are measured, it may be necessary to set performance measures on the outputs or the results rather than the individual functional performances. If a company set a goal as the improved competitiveness through the smoothed material flow, the measurement at strategic level might be the inventory turnover as the results of the total activities. At tactical level, the company may plan to improve information flow to achieve the smooth material flow. In this case, the accuracy of forecasting techniques or the relationship with suppliers and customers may be measured. At operational level, frequency of delivery, order quantity, or inventory level may be measured. Examples of performance measures at different managerial levels are given by Gunasekaran *et al* (2001) in Appendix.

To investigate the performances at strategic level such as the total performance in a part of supply chain from the direct supplier to the direct customer, it may be required that the supply chain has fundamentals of supply chain approaches. he total performance improvement by linking the operational level to the strategic level. The performance measurement in the strategic level as well as the performance measurement on the links between strategic and operational levels is also recommended as the further step of the supply chain performance measurement.

(3) Concurrent performance measurement in the on-going data

Since this project totally relied on the historical data in the past not on the present on-going data, the actual environment such as the daily communication with suppliers and customers or the break down at the production line could not closely investigated with the numerical data. Therefore, it is suggested that the performance measurement should be conducted at actual business environment as well.

(4) Direct supplier and customer performance measurement

The process intended to measure the suppliers and customers by the limited data from them. However, and if possible, the direct communication with the suppliers and customers will be more effective for the measurement. Once the Deliver performance of the supplier and Source performance of the customer is fairly known by the internal information, it could be expected that the performance of the other processes could be obtained through the better communication. In that case, the process can be utilised in the supplier and the customer as well. Hence the total performance measurement from supplier's supplier to customer's customer can be done. It could be academic purpose only since there are still boundaries between companies, but the result could be returned to the supply chain as well. However, the attempt to measure the direct suppliers and the direct customers will give a company more advantages on supply chain management.

(5) Application for the other industries

As mentioned in the conclusion, the supply chain performance measurement process was tested only in Thai automotive industry although the form seems to be generic. The framework could be applied to a case company assuming that the company has a typical business practice in the industry where similar SMEs dominate. Hence, it is expected that the framework can be applied to the other companies in the industry. In addition, it can be expected that the framework can be applied to the other industries if the industry has the similar business practices or the similar issues in the industry with Thai automotive industry.

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APPENDIX

Examples of Performance Measures from Previous Researches

Author	Measurement Area / Category	Examples of Measures
Andersen Consulting, Cambridge University, Cardiff Business School From a module note of Supply Chain Management, WMG	Supply chain quality	Incoming defects
		Internal defect rate
		Customer complaints
	Supply chain inventories	Stocks of major, high volume incoming parts
		Inventories in assembly areas
		Finished goods inventories
		Stock turn ratios
	Time in the supply chain	Incoming parts frequency of delivery
		Instruction time to assembly (hours before production)
		Journey time to customer
		Frequency of delivery to customer
	Scheduling	Time between firm supplier order and actual delivery
		Variability of schedule to major supplier
		Internal scheduling practice (% use of pull system)
		Time between final firm order and shipment
		Variability of schedule from major customer
Beamon (1999), pp.280-286	Resources	Total cost
		Distribution costs
		Manufacturing cost
		- Inventory
		- Inventory investment
		- Inventory obsolescence
		- Work-in-process
		- Finished goods
		Return on investment (ROI)
	Output	Sales
		Profit
		Fill rate
		- Target fill rate achievement
		- Average item fill rate
		On-time deliveries
		- Product lateness
		- Average lateness of orders
		- Average earliness of orders
		- Percent on-time deliveries
		Backorder/Stock-out
		- Stock-out probability
		- Number of backorders
		- Number of stock-outs
		- Average backorder level
		Customer response time
		Manufacturing lead time. complaints registered
		Shipping errors
		Customer complaints
	Flexibility	Reductions in the number of backorders
		Reductions in the number of lost sales

		Reductions in the number of late orders
		Increased customer satisfaction
		Ability to respond to and accommodate demand variations, such as seasonality
		Ability to respond to and accommodate periods of poor manufacturing performance (machine breakdowns)
		Ability to respond to and accommodate periods of poor supplier performance
		Ability to respond to and accommodate periods of poor delivery performance
		Ability to respond to and accommodate new products, new markets, or new competitors
Bowersox and Closs (1996), pp.679 "Integrated Supply Chain Metric Framework" Source: PRTM Consulting (October, 1994), "Integrated Supply Chain Performance Measurement: A Multi-Industry Consortium Recommendation," Weston, Mass	Customer Satisfaction / Quality	Perfect order fulfilment
		Customer satisfaction
		Product quality
		Delivery-to-commit date
		Warranty costs, returns, and allowances
		Customer inquiry response time
	Time	Order fulfilment lead time
		Source/Make cycle time
		Supply chain response time
		Production plan achievement
	Costs	Total supply chain costs
		Value-added productivity
	Assets	Cash-to-cash cycle time
		Inventory days of supply
		Asset performance
		Forecast accuracy
		Inventory obsolescence
		Capacity utilisation
Bowersox *et al* (2002), pp.557 "Typical Performance Metrics"	Cost Management	Total cost
		Cost per unit
		Cost as a % of sales
		Inbound freight
		Outbound freight
		Administrative
		Warehouse order processing
		Direct labour
		Comparison of actual versus budget
		Cost trend analysis
		Direct product profitability
		Customer segment profitability
		Inventory carrying
		Cost of returned goods
		Cost of damage
		Cost of service failures
		Cost of back order
	Customer Service	Fill rate
		Stockouts
		Shipping errors
		On-time delivery
		Back orders
		Cycle time

		Delivery consistency
		Response time to inquiries
		Response accuracy
		Complete orders
		Customer complaints
		Sales force complaints
		Overall reliability
		Overall satisfaction
	Quality	Damage frequency
		Order entry accuracy
		Picking / shipping accuracy
		Document / invoicing accuracy
		Information availability
		Information accuracy
		Number of credit claims
		Number of customer returns
	Productivity	Units shipped per employee
		Units per labour dollar
		Order per sales representative
		Comparison to historical standard
		Goal programs
		Productivity index
		Equipment downtime
		Order entry productivity
		Warehouse labour productivity
		Transportation labour productivity
	Asset Management	Inventory turns
		Inventory levels, number of days supply
		Obsolete inventory
		Return on net assets
		Return on investment
		Inventory classification (ABC)
		Economic value-added (EVA)
Chan *et al* (2003), pp.636-637	Qualitative	Customer satisfaction
		Flexibility
		Information and material flow integration
		Effective risk management
		Supplier performance
	Quantitative (cost)	Cost minimisation
		Profit maximisation
		Inventory investment minimisation
		Return on investment maximisation
	Quantitative (customer)	Fill rate maximisation
		Product lateness minimisation Customer response time minimisation
		Lead time minimisation
		Function duplication minimisation
	Quantitative (productivity)	Capacity utilisation
		Resources utilisation maximisation
Gunasekaran *et al* (2001), pp.82-85 "A framework on	Strategic	Total supply chain cycle time
		Total cash flow time
		Customer query time
		Level of customer perceived value of product

metrics for the performance evaluation of a supply chain"		Net profit vs. productivity ratio
		Rate of return on investment
		Range of product and services
		Variations against budget
		Order lead time
		Flexibility of service systems to meet particular customer needs
		Buyer-supplier partnership level
		Supplier lead time against industry norm
		Level of supplier's defect free deliveries
		Delivery lead time
		Delivery performance
	Tactical	Accuracy of forecasting techniques
		Product development cycle time
		Order entry methods
		Effectiveness of delivery invoice methods
		Purchase order cycle time
		Planned process cycle time
		Effectiveness of master production schedule
		Supplier assistance in solving technical problems
		Supplier ability to respond to quality problems
		Supplier cost saving initiatives
		Supplier's booking in procedures
		Delivery reliability
		Responsiveness to urgent deliveries
		Effectiveness of distribution planning schedule
	Operational	Cost per operation hour
		Information carrying cost
		Capacity utilization
		Total inventory
		- Incoming stock level
		- Work-in-progress
		- Scrap level
		- Finished goods in transit
		Supplier rejection rate
		Quality of delivery documentation
		Efficiency of purchase order cycle time
		Frequency of delivery
		Driver reliability for performance
		Quality of delivered goods
		Achievement of defect free deliveries
Hines *et al* (2000), pp.268-269 "Performance Indicators and Potential Measures"	Inventory Management / Cost of Working Capital	Level of inventory
		Turnover ratio
		No. of stock-outs
		Inventory as a % of total purchases
		Inventory as a % of sales
		Inactive inventory as a % of total inventory
		Amount of obsolescence (predicted usage)
	Lead time Performance	Cycle time reduction
		No. of requisitions processed per period
		% of times products released to schedule
	Customer Delivery Service	Size of order backlog
		No. and frequency of complaints
		No. of deliveries on time

		No. and frequency of over/under deliveries
		% deliveries to rush order
		No. and value of invoice adjustments
		Customer satisfaction index
	Quality	% of rejections / rework
		Durability / reliability
		Ease of servicing
		% spend on scrap/salvage
		Quality of documentation
	Purchasing Skills	Team building
		Negotiation ability
		Commodity knowledge
		Level of purchasing analysis
		Supply market awareness
		Staff education levels / professional qualifications
		No. and type of training courses
		Training expenditure per head
		Productivity per head
	Purchasing Processes	Work load (suppliers/orders per buyer)
		Use of Vendor rating systems
		Supply base rationalisation
		Collaborative agreements
		Technological capability (IT)
		% total purchases processed through EDI
		% total purchase transactions processed through EDI
		% suppliers with whom EDI is used
	Cost of Purchases	'Business ratio' (cost: spend)
		Purchases / sales * 10
		Total cost of ownership
		Opportunity cost if invested elsewhere
	Impact on Profit	Actual vs. target price
		Actual vs. market price
		Price savings per period
		% reduction on sales / assets
		Value of total cost reduction through process improvement
		Credit terms
		Payables
		Payable days
		Hedging / currency management
	Purchasing Leverage	Level of competition achieved (by value and volume)
		No. of approved suppliers
		Average order size (MOQ)
		No. of new suppliers contacted
		Supply base review
		No. of alternative supply sources
		Group strength consolidated
	Continuous Improvement	Value analysis / value engineering
		No. supplier / joint innovations generated
		Time to bring new products to market
		Safety and Environment quality ratings
		Non-traditional purchasing (% purchases handled by purchasing department)

		Share of preferred supplier business
		Scheduling improvements (disruptions to suppliers / vehicle waiting times)
		No. of zero-defect status suppliers
		Suppliers per purchasing employee
		Suppliers per purchasing professional
		Order size constraints
	Professionalism	Provision of order status information
		Internal customer contact intervals
		Ordering convenience
		Documentation quality
		No. of anchor people vs. business managers
		Response times to queries
		Order confirmation time
		Quotation response time
	Innovation	Buyer targets for quality improvement
		Learning curve analysis
		No. of cost saving ideas
		Research funding
Hvolby and Thorstenson (2000), pp.330 Case of Danish SMEs	Delivery precision	
	Lead time	
	Capacity utilisation	
	Quality levels	
	Cost calculations	
Morgan (2004), pp.524 "A selection of traditional historic performance measures"	Financial	Creditor days
		Debtor days
		Dividend cover
		Stock turnover
		PE ratio
		Net asset turnover
		ROCE
		ROE
		Current ratio
		Gross profit
		ROOA
		Return on sales
		Sales per square meter
		Gearing
	Operations	Operations lead time
		Inventory
		Stock turn
		Set-up time
		Labour utility
		Machine utility
		Work in progress
		Employee turnover
		Direct productivity
		Indirect productivity
		Supplier performance
		Variances
		Process time
		Number of accidents
	Marketing	Market share

		Orders on hand
		Order lead time
		Number of complaints
		New product introduction
		Repeat orders
		Delivery performance
		Time to market
		Warranty claims
		Returns
		Service visits
		First pick %
		First drop %
		Transport utility
	Quality	% of rework
		% of rejects
		% of conformance
		% of scrap
		Quality administrative costs
		Recall costs
		Liability costs
		% of penalties
		% of errors
		Prevention costs
		Quality training costs
		Product testing
		Performance testing
		Laboratory costs
Morgan (2004), pp.532 "Typical logistic system performance measures"	Financial performance	Stock turn
		ROI
		ROA
		ABC control
		EVA
		EPS
	Cost performance	Cost per unit
		Cost per sale
		Inbound freight
		Outbound freight
		Order processing cost
		Direct/indirect labour cost
		Direct product profitability
		Inventory carrying cost
		Cost of returns
		Damage costs
		Backorder costs
	Customer service	On-time deliveries
		Number of stock-outs
		Delivery cycle time
		Enquiry response time
		Number of shipping errors
		Number of customer complaints
		Delivery shortages
		Number of packages damaged
		Reliability SLA performance
	Quality	Handling damage

		Information integrity
		Paperwork accuracy
		Paperwork delivery
		Number of damage claims
		Picking and shipping accuracy
		Labour turnover
	Operational productivity	Pick rate per employee
		Units shipped per employee
		Average used capacity
		Stock velocity
		Average pick time per order
		Transport capacity utility
		Equipment uptime
		Time per order processed
Neely *et al* (1995), pp.83-95 "The multiple dimensions of quality, time, cost and flexibility"	Quality	Performance
		Features
		Reliability
		Conformance
		Technical durability
		Serviceability
		Aesthetics
		Perceived quality
		Humanity
		Value
	Time	Manufacturing lead time
		Rate of production introduction
		Delivery lead time
		Due-date performance
		Frequency of delivery
	Cost	Manufacturing cost
		Value added
		Selling price
		Running cost
		Service cost
	Flexibility	Material quality
		Output quality
		New product
		Modify product
		Deliverability
		Volume
		Mix
		Resource mix
Stewart (1995), pp.41-44	Delivery performance	Delivery-to-request
		Delivery-to-commit data
		Order fill lead time
	Flexibility and responsiveness	Production flexibility
		Re-plan cycle
		Cumulative source/make cycle time
	Logistics cost	Total logistics cost
		Order management costs
	Asset management	Inventory days of supply
		Days of sale outstanding

BIOGRAPHY

Shinji Miyawaki was born on 17 August 1979 in Hiroshima, Japan. He received his Bachelor Degree in Mechanical Engineering from Okayama University, Japan, in 2003. After receiving the degree, he continued his study Master Degree at the Regional Centre for Manufacturing Systems Engineering, Faculty of Engineering, Chulalongkorn University, Thailand and University of Warwick, United Kingdom.