The Definition of Appropriate Shopfloor Performance Measures Using the Theory of Constraints Philosophy and Study of Shopfloor Performance Measures Application in New Zealand Manufacturers

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V T Wongsonegoro

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"When you measure what you are speaking about and express it in numbers, you know something about it. Otherwise, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in thought advanced to the stage of science." - Lord Kelvin, 1824-1907.

Abstract

Shopfloor performance measures have significant impact on the overall performance of a manufacturing organisation. Measures are used in many ways to support the decision making function across an organisation.

Many research suggest that many shopfloor measures used by manufacturers were derived when producers dominated market (Srikanth et al, 1995; Goldratt, 1988, 1990; Stein, 1994; Kaplan et al, 1992). Cost control was the major factor in ensuring profitable operations (Srikanth et al, 1995).

Today cost-based measures are no longer appropriate as other critical dimensions are needed to maintain manufacturing competitiveness (Goldratt, 1990). The market condition dictates such things as faster lead times, increased variety of quality products and cost effective purchasing. Increasing competition has also forced producers to be more proactive in seizing every sales opportunity available. Cost-based measures fails because they focus too much on local improvements and short term performance that do not necessarily translate into overall improvement (Goldratt, 1992).

Today manufacturing competitiveness come in three key dimensions: product, price and responsiveness (Goldratt, 1986). Shorter lead times and due date performance assist to achieve manufacturing responsiveness. In turn, these key factors rely on good shopfloor performance assisted by shopfloor measures.

Theory of Constraints synchronisation principles were looked at and analysed to explore how they could be used to derive working shopfloor measures. Synchronisation of activities is important to bring about the desired performance through synergy. The step by step approaches of the Five Focusing Steps and the synchronisation mechanism offered by the DBR scheduling could be used as the benchmark whereby shopfloor measures are derived. The TOC performance measurement, Throughput, Inventory and Operating Expense measures, should be the objectives of shopfloor measures achievements.

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Glossary of Terms

The followings are the definitions of some popular terms used in this document (in alphabetical order):

1. CCR: Umble et al (1990) describes Capacity Constraint Resource (CCR) as any resource which if not properly scheduled and managed, is likely to cause the actual flow of product through the plant to deviate from the planned product flow.
2. Dependent Events: A chain of events or activities that cannot overlap each other to give the full results or products.
3. Global Optima: Achievement of organisation wide or overall improvement that should also cover localised improvement (Goldratt, 1992).
4. JIT: Just-In-Time (JIT) is defined in Schermerhorn (1993) as a scheduling system that attempts to reduce costs and improve workflow by scheduling materials to arrive at work centres as they are needed.
5. Local Optima: Achievement of localised improvement that may not have any effect on overall improvement (Goldratt, 1992).
6. Shopfloor Performance Measures: A metric used to quantify the efficiency and/or effectiveness of an action at the shopfloor level (see Chapter 3 for detailed descriptions of this term and its associated topics).
7. Sub-system: A smaller component of a larger system that operates to its benefit (Schermerhorn, 1993). This could be interpreted as those individual but interrelated departments working together in an organisation.
8. System: A collection of interrelated parts that function together to achieve a common purpose (Schermerhorn, 1993).
9. System's Constraint: Anything that prevents the system advancing towards its goal.
10. The Goal: The 'Goal' or simply the 'goal' will be utilised throughput this document and Goldratt (1992) defines the goal of for-profit enterprise as "to make (more) money now and in the future".
11. TOC: Dettmer (1994) describes Dr. EM Goldratt's *Theory of Constraints* (TOC) as a *system* improvement philosophy. TOC is a paradigm, which includes not only its concepts and guiding principles, but also its tools and applications. Examples of TOC applications are the *Thinking Process* and the *Drum Buffer Rope* scheduling mechanism.

12. TQM: Total Quality Management (TQM) is defined in Schermerhorn (1993) as a style of managing an organisation wide commitment to continuous improvement and focusing on meeting customer needs.
13. WCM: *World Class Manufacturing* (WCM) is a term first widely publicised in studies developed by RJ Schonberger (1986). Although the meaning of world class is in the eye of beholder, there is general agreement that a WCM is a firm that has attained a high level of manufacturing capability, used that capability to gain competitive advantage and constantly strives to improve those capabilities (Leong et al, 1995).

Additional and more complete descriptions of other terms used will be explained in the body of this document.

Chapter One: Introduction

1.0 Research Background

Goldratt (1992) suggests that in order to understand and to derive working policies a goal needs to be formulated. He suggests that the operation of a profit-making organisation should be focused towards the *Throughput World* where the goal is to make (more) money now and in the future. Other goals, such as producing quality products, improving human resource outcome, value for money and rapid product cycles are some means to achieve the ultimate goal of making money. This does not imply that the focus on money disregards other key factors such as quality- related issues and meeting employees' interests. In fact, a responsible organisation would be required to satisfy other key prerequisites such as applying key quality management principles, maintaining a balanced and safe work environment.

In order to achieve the goal a manufacturing organisation must possess distinctive competitive dimensions that can be categorised into three major area with two corresponding sub-majors each (Goldratt et al, 1986).

Major Categories	**Subcategories**
1. Product	• Quality • Engineering
2. Price	• Higher margins • Lower investment per unit
3. Responsiveness	• Due date performance • Shorter lead-time

Table 1.1: Manufacturing Competitive Edge.

The first competitive edge signifies the need to manufacture quality products that are fit for the purpose and meet customers' requirements. It is commonly known that quality is a key factor to attracting and securing sales, and also to ensure smooth manufacturing processes. Quality products and processes can be achieved through excellence in engineering.

As companies are able to offer similar products to the market, the next competitive edge would come from being able to have higher margins (i.e. lower overall costs) and lower investment per unit in the overall production. These two factors would allow a company to flex its product pricing to suit the targeted market (Goldratt, 1994).

Responsiveness to demand becomes crucial to attracting and securing sales, as market is flooded with quality products at competitive prices. In order to maintain and/or improve market share a manufacturer must be able to meet the agreed due date which appears to keep getting shorter. One of the prerequisites to achieve good due date performance is through shortening manufacturing lead-time.

In order to ensure progress towards achieving the future goals, company management must put in place a performance measurement system whereby measures are used to gauge past actions and the quantified data will be used to determine future actions. This includes measuring personnel and their activities to provide some indication on the organisation's capability to reach the targeted objectives.

Dumond (1994) states that performance measurement (PM) is a research topic that covers many disciplines such as production operations and finance. It involves key internal factors of managing organisation such as defining objectives, developing means to achieve these objectives, and developing control and feedback mechanisms. A performance measurement system also involves external affairs functions such as customer service and customer focus groups. Subject to what it is to be measured and how measures are applied, measures can have a different impact on an organisation's overall performance. Performance measurement that relates to production operations at the shopfloor level will be the main focus of this study. Their reasons are described in the following paragraphs.

It is commonly known that the measure of performance of for-profit organisation is found by examining its financial state. An absolute measure to judge this type of company is Net Profit (NP) which generally appears in company's Profit and Loss statement (Goldratt, 1990). In addition, relative measures such as Return on Investment (ROI), Return on Assets (ROA) and Return on Shareholders' Equity (ROSE or ROE) can be used to measure company's bottom line (Goldratt, 1990). A third measure, "cashflow", is a necessary condition that measures the flow of money in and out of organisation (Goldratt, 1990). The latter suggest that a bad cash flow following successful delivery of goods and/or services would result in a negative effect as operating expense increased while sales revenue stay the same.

However, these financial measures are less effective when used on a daily basis as it would be difficult to relate actions directly to financial measures such as NP and ROI. Thus, in order to provide mechanism to support the attainment of the financial objectives, Goldratt (1990) suggests that the financial goal of making money be achieved by increasing Throughput (T) and simultaneously decreasing Inventory (I) and Operating Expense (OE). T, I and OE performance measures also form a part of the Theory of Constraints performance measurement framework.

Goldratt (1990) describes T, I and OE as operational measures that can be used as a day-by-day decision making tool. This is due to their relevance to everyday activities involved in the production environment. Their definitions are shown in Table 1.2.

Operational Measure	Descriptions
1. Throughput (T)	The rate at which money is generated through sales (sales revenue minus raw material cost).
2. Inventory (I)	The amount of money tied up in materials that the company intends to sell.
3. Operating Expense (OE)	The money spent to convert Inventory into Throughput.

Table 1.2: Definitions of T, I and OE Operational Measures.

The following describes how T, I and OE can be used to calculate NP and ROI (Goldratt, 1990):

Financial Measures	T,I and OE Formulas
1. NP	T – OE
2. ROI	(T - OE)/ I

Table 1.3: T, I and OE Formulas to Calculate NP and ROI.

Relationship between T, I and OE, and other financial measures suggest that there is a hierarchy of measures which roughly parallels the number of management levels in an organisation. This suggests that the measures used at various functions within the company's management hierarchy should be inter-related and not applied in isolation. Figure 1.1 shows a simplistic view of the measures hierarchy.

Figure 1.1: Hierarchy of Measures.

One of the many ways to achieve the competitive advantages shown in Table 1.1 is through excellent shopfloor (i.e. the third and lowest level management) performance, which is inherently assisted by the application of shopfloor measures. This lowest management level is as important as any other unit in the organisation because the provision of goods and services typically originates at the shopfloor level.

Due to the type of decisions to be made, most shopfloor measures are likely to be of non-financial measure type. However, Rangone (1996) states that the use of non-financial measures in performance measurement implies two major problems:

1. The selection of a proper set of measures capable of assessing and controlling all critical factors that act on the competitive priorities.
2. The integration of those several measures, expressed in heterogeneous units, into a single evaluation of the overall performance of a manufacturing department (i.e. lower level management).

Although most shopfloor measures can be of non-financial type their application will impact an organisation's financial performance. In addition, at this level specific measures are required to accompany a variety of activities which will be largely different from one organisation to another. Therefore, interpretation of Throughput, Inventory and Operating Expense at the shopfloor level can be rather complex. Furthermore, the realisation of shopfloor measures can be critical in ensuring that T is up while simultaneously I and OE are down. This further reinforces that the type of shopfloor measures and their applications are important as a means to bring an organisation closer to its objectives.

In order to provide a mechanism in which appropriate shopfloor measures can be derived, this study focuses on the Theory of Constraints (TOC) applications due to strong interest and the availability of expertise at Massey University. Detailed descriptions of TOC and its key components are shown in Chapter 3. In addition, TOC has been chosen partly because of its success track records shown in the literature, and some of these are the works by Lippa (1990), Cook (1994), Fawcett et al (1991) and De Colvenaer et al (1992).

1.2 Study Objectives

From the previous discussions, the following key objectives were investigated in this research, which were to identify and analyse:

1. The problems with using traditional cost accounting based measures.
2. The performance measurement system.
3. The criteria and principles for developing appropriate shopfloor measures.
4. The impact of selected shopfloor measures on overall organisation performance.

In order to fully comprehend the lower management level performance it was decided to study the application of shopfloor measures in New Zealand manufacturers. This initiated the development of a research survey, which helped identify and analyse the following objectives:

5. The application of shopfloor measures in popular use.
6. Common production related problems.
7. Other key production operations practice.

1.3 Importance of the Study

At the time of the survey, the New Zealand manufacturing industry was undergoing major re-structuring following the decision to reduce tariffs by the National Government early in 1998 (New Zealand Year Book, 1998). Cheaper imported goods and increased product variety and volume have made it difficult for local manufacturers to compete as they have significantly larger overhead costs versus volume of production when compared with many of their overseas competitors. Particularly affected are those companies engaging in worldwide competition such as the motor vehicle assemblers.

As a result of the tariff reductions, a number of companies have reduced their workforce and/or gone into voluntarily closure, as their operations become non-viable. Many of New Zealand's largest employers such as the car manufacturing and assembly industries had closed down in late 1997 or as late as the end of 1998. Companies such as Toyota (with approximately 350 employees), Ford and Mazda (with approximately 350 employees and 900 companies respectively) have either closed down or will be closed down near the end of 1998[1]. These negative effects have questioned the competitiveness of some New Zealand manufacturers.

This study helped clarify the performance measurement functions and examined development criteria of appropriate shopfloor measures. In addition, other key performance measurement issues were also analysed. These included such things as the link between shopfloor measures to other organisational functions, key operational policies and methods that enhance control and synchronise activities throughout organisation.

The survey research helped in the study of the shopfloor measures used by the New Zealand manufacturers. Some of the key benefits include analysis of the effectiveness and the usefulness of selected shopfloor measures, the identification of the occurrence rate and the financial impact of particular production related problems.

1.4 Organisation of the Study

Chapter Two outlines the problems with traditional performance measures. The section started with an overview of the changes that had taken place in the 20th century and how these changes have affected performance measurement. This was followed by a discussion on the role of management accounting in the manufacturing organisation's decision making function. The next section outlines the limitations and the problems of traditional performance measurement in the manufacturing environment. A Current Reality Tree was developed to further describe the problems and to trace the root cause using cause and effect mechanism.

Chapter Three examines the performance measurement system design. The discussion starts with an outline of performance measurement design attributes. The second half of this chapter examines selected authors' work. Most notable is the Theory of Constraints performance measurement system and its synchronisation principles that formed the foundation of this study. It is important to synchronise shopfloor activities, as local achievements do not necessarily lead to overall company performance and that there will be certain amount of resources available to carry out the manufacturing tasks to the agreed standards. The synchronisation principles formed the backbone of the Drum Buffer Rope scheduling that could be used to derive shopfloor policies and measures.

Chapter Four assesses the ideas collected from the previous two chapters into a series of criteria for developing appropriate shopfloor measures. The criteria developed were mostly gathered from Goldratt's work and selected other authors' work under the Theory of Constraints umbrella. Also included is a proposal of a step by step process to derive measures.

Chapter Five illustrates the survey research methodology. A survey research was carried out with the objective to analyse and examine the application of shopfloor measures in New Zealand manufacturers. This chapter discusses in detail such things as the survey's objectives and its benefits, the survey research design and the survey

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[1] These figures were gathered during plant visits made in 1996 as well as various media reports during September and December 1998.

instrument development process. It also included a discussion on how product flow and traditional measures affect the performance of production operations.

Chapter Six details the analysis of the survey results. These are mainly interpretations of statistical data as a means to obtaining the predetermined objectives. The knowledge gained helped picture the application of shopfloor measures, the significance of production related problems and other key performance issues in the New Zealand manufacturers who were surveyed. Chapter Seven includes the conclusion from this study, and Chapter Eight provides recommendations for future work.

Chapter Two: The Problems with Traditional Performance Measures

2.0 Introduction

This chapter aims to examine the problems associated with traditional measures. The discussion starts with recounting the manufacturing industry evolution that took place in the 20th century. During this time significant changes have taken place in the manufacturing scene that effect the design and the application of the performance measurement system. This is followed by an outline of selected authors' work that summarises the underlying problem of the traditional management philosophy and other associated measures. Specific examples of these problems in the manufacturing environment completed the discussions. In addition, cause and effect mechanism that is part of Theory of Constraints Thinking Process application was developed to help verify some of the problems associated with using the traditional measures. It assisted in confirming the need to adopt more appropriate performance measurement methods.

2.1 The Manufacturing Industry Performance Measurement Evolution

In the early 20th century, manufacturers dominated the market as the demand for goods worldwide out-weighted supply (Srikanth and Robertson, 1995). Manufacturers had more influence than consumers did. This type of market was called the *seller's market* and controlling costs could enhance profitability. Plossl (1990) further state that the early 20th century manufacturing environment was characterised by:

- Throughput rates of products controlled by direct labour.
- Slowly changing technology resulting in long product life cycles and infrequent major design changes.
- A management focus on labour efficiency.
- Other resources (like capital invested in machines and skilled staff) used to enhance direct labour.

Therefore, measures used were called the *cost-accounting based measures* and to suit these circumstances the principal characteristics of traditional cost system were:

- Direct labour costs had a prominent role.
- The bulk of overhead costs were closely related to direct labour.
- Cost centre activities revolved around direct labour.
- Direct manufacturing costs varied largely with throughput and hence direct labour.

However, in the latter half of the 20th century, technological improvements and other changes in the business world resulted in more greatly improved quality products available than the market demanded in many sectors of industry (Srikanth and Robertson, 1995).

This situation resulted in the consumers gaining control over the manufacturers and hence gave consumers the ability to dictate prices, their influence in manufacturers' production operations. This type of market is appropriately termed as the *consumer's market* and suggests that cost accounting based measures may be no longer appropriate for managing business performance (Srikanth and Robertson, 1995; Plossl, 1990; Ghalayini et al, 1996; Maskell, 1991).

The change to a *consumer's market* from a *seller's market* has necessitated changes in the way manufacturing company's production operations are managed (Kaplan et al, 1992; Umble et al, 1990). In order to regain a competitive edge companies not only shifted their strategic priorities from low cost production to quality, flexibility, short lead time and dependable delivery, but also implemented new technologies and philosophies of production management (Ghalayini et al, 1996). Some of the well-known improvement methods are Flexible Manufacturing Systems (FMS), Total Quality Management (TQM) and Just-in-Time (JIT). These changes have also initiated a review of how measures should be derived and applied (Goldratt, 1990).

Goldratt (1992) states that cost accounting is the number one enemy to productivity due to its short-term focus to achieve company-wide performance and the goal of making money now and in the future. Cost accounting's emphasis on numbers alone such as cost reduction and individual unit efficiency would only result in localised improvement that do not necessarily translate to overall or company-wide performance (this is further explained later in this chapter).

Measures are important because they play a significant role in supporting action(s) and the decision making functions. Measures provide data and information needed for formulating actions to bridge current progress and future goals. Therefore, measures need to be defined properly so that appropriate formula can be prescribed to address the core problem(s)[2] that prevent the attainment of company wide goals. In order to gain understanding of how cost accounting influences the performance of a manufacturing organisation, there is a need to explain the role of management accounting in a manufacturer's decision making function.

2.2 The Role of Management Accounting in the Manufacturing Organisations

Drury et al (1998) state that the description of management accounting function was based on the following analogy: the management accountant was viewed as the ship's pilot under the direction of a captain. This can be further described by the primary role of management accountants in manufacturing organisation which is to provide a financial analysis of management decisions and activities (Fry et al, 1995). Therefore, the reports generated by the management accounting system are to be used to evaluate organisation's performance and to evaluate the performance of the operations managers (Goldratt, 1990).

Management accounting is fairly new having evolved from simple cost accounting system (Fry et al, 1995). Two primary purposes of the cost accounting system were to value inventory and to determine cost of goods sold (CGS) for the plant income statement, each of which is a requirement of the financial accounting system (Johnson et al, 1987).

External pressure such as the capital market where investment decisions are made in a quick succession could forced a manufacturer to put in place policies for short-term performance so that the company appears to be financially sound at all times. This

[2] Goldratt (1992) defines 'core problem' as the root cause of all undesirable effects.

means there is a vast potential for company management to trade necessary long-term policies with policies to gain short-term performance.

These phenomena and their effects on manufacturing operations can be described further by the following illustration[3].

> "In addition to the fact that management accounting reports are the score card of an operation manager's performance, another reason for the sometime overemphasis by these managers on financial accounting reports is the short term nature of US capital markets. Wall Street investors are required by numerous regulatory bodies to keep a 'hands-off' relationship with the companies they own. Further, institutional investors such as pension funds, mutual funds, etc., are required by law to seek a maximum rate of return on their investment. Since these institutional investors hold the majority of stock ownership in US companies, stocks are often traded like commodities as investors seek maximum return. Given this hands-off relationship between companies they own, and the short duration for which many stocks are held, it is necessary for investors to rely almost exclusively on short term financial reports to gauge the success of their investment. This further encourages managers to emphasis short-term financial performance.....linking the management accounting system to the financial accounting system strongly encourages operations managers to emphasise plant financial performance rather than other, perhaps more meaningful, performance criteria. And since the primary financial accounting report, the income statement, is normally generated, monthly operations managers are encouraged to focus on short term financial performance rather than a longer term period. Indeed, in a recent study by Industrial Research Institute (Jacobs, 1991), operations managers identified the two major threats to US competitiveness as external financial pressures and short term management focus" – Fry et al (1995).

The above shows how external pressure and the expectations of wary investors influence the internal management functions and the development of manufacturing strategy required achieving the stated financial goal on a short-term basis. Moreover, due to a reliance on management accounting performance as operational management scorecard the measures used at the shopfloor often had a similar, if not the same, short term performance focus (see Appendix D: Traditional Manufacturing Measures).

[3] Although the illustration mentioned only US companies, similar circumstances are found everywhere else as US financial systems and management practices have significant influence in the rest of the world. US refers to the United States of America.

2.3 Limitations of Traditional Cost Accounting Based Measures

Maskell (1991) summarises the problems with traditional management accounting and its related performance measures into the following classifications:

Classification	Descriptions
1. Lack of Relevance	• Management accounting reports are not directly related to the manufacturing strategy. • Financial measures are not meaningful for the control of production and distribution operations. • The application of cost accounting to pricing decisions is frequently irrelevant and misleading.
2. Cost Distortion	• Traditional cost accounting is concerned with cost elements. The pattern of cost elements has changed in recent years, and this detailed analysis is less important. • The distinction between direct and indirect costs is not rigid as it used to be. The same is true of variable and fixed costs. • The traditional methods of apportioning overheads can significantly distort product costs.
3. Inflexibility	• Traditional management accounting reports do not vary from plant to plant within the organisation. Similarly, they usually do not change over time as needs of the business change. • Cost accounting reports frequently are received too late to be of value. • Cost accounting reports frequently are viewed with disdain by operations managers because they do not help them with their job and because they are often used to censure the operations manager when variances are not favourable.
4. Impediment to Progress in World Class Manufacturing	• Traditional methods of assessing the pay back on capital projects can impede the introduction of world class manufacturing. • Cost accounting often causes managers to undertake wasteful and unnecessary tasks in order to make the figures look good. • Concentrating on machine and labour efficiency rates encourages the production of large batch quantities. • Overhead absorption variances encourage large batch sizes and overproduction. • Cost accounting requires much detailed data that is costly to obtain. • Cost accounting reinforces the entrenched ideas and outmoded methods that need to be replaced.

5. Subjection to the Needs of Financial Accounting	• Too often cost accounts are regarded as a subsidiary ledger of financial accounts. To be of value, management accounting systems must be based on different methods and assumptions than on the financial accounts. These methods apply to such issues as inventory valuation, overhead absorption and accounting period.

Table 2.1: Summary of Problems with Traditional Accounting Based Measures – adapted from Maskell (1991).

Ghalayini et al (1996) further summarised the following eight most commonly cited limitations of traditional performance measures from a range of literature that include Kaplan (1990) and Fisher (1992).

Limitations	**Descriptions**
1. Traditional Management Accounting Systems	See Table 2.1
2. Lagging Metrics	Financial reports are usually closed monthly thus they are lagging metrics that are a result of past decisions.
3. Corporate Strategy	Traditional performance measures rarely incorporated strategy. Rather the objectives have been to minimise costs, increase labour efficiency and machine utilisation.
4. Relevance to Practice	Traditional measures try to quantify performance and other improvement efforts in financial terms. Yet, most improvement efforts are difficult to quantify in dollars (i.e. lead time reduction, customer satisfaction and product quality). In addition, operators find typical financial reports difficult to understand which leads to frustration and dissatisfaction. As a result, traditional performance measures are often ignored in practice at the factory shopfloor level.
5. Inflexible	Traditional financial reports are inflexible in that they have a predetermined format which is used across all departments. However, even departments within a company have their own characteristics and priorities. Thus, measures used in one department may not be relevant for others.
6. Expensive	The preparation of traditional financial reports requires an extensive amount of data which is usually expensive to obtain.
7. Continuous Improvement	Fisher (1992) argues that setting standards for performance measures in general conflicts with continuous improvement. "If standards were not carefully set, they had the effect of setting norms rather than motivating improvement. Workers may hesitate to perform to their maximum if they realise that the standard for upcoming periods may be revised upward

	by current results"
8. Customer Requirements and Management Techniques	Maskell (1991) argues that traditional performance measures are no longer useful since in order to meet customer requirements of higher quality products, shorter lead time and lower cost, management have to give shopfloor operators more responsibility and authority in their work. Consequently, traditional financial reports used by middle managers do not reflect a more autonomous management approach.

Table 2.2: General Limitations of Traditional Performance Measures – adapted from Ghalayini et al (1996).

2.4 The Problems with the Traditional Performance Measurement in the Manufacturing Environment

Umble et al (1990) state that the standard cost procedures and the performance measures supported by these cost systems all too often trigger dysfunctional actions within the organisation in general and specifically within the manufacturing system. The origin of these dysfunctional actions stems from the ideology of maximising the efficiency of each individual work centres instead of maximising the overall performance of the organisation or system.

Traditional cost accounting advocates increasing efficiency from all corners of the organisation to lower unit costs to form the path to lowering overall production costs. This came from the suggestion that the sum of individual unit efficiency would result in the efficiency of the overall system (Goldratt, 1992). This is also known as "the sum of local optima is the sum of global optima". Examples of this notion can be seen from such policies as 100% activation of all work centres and bulk discounted purchasing.

However, Goldratt (1992) states that a system that aims to reach 100% efficiencies from all its resources would become an inefficient system. This is due to the existence of system's constraints coupled with two critical factors termed "dependent events" and "statistical fluctuations". Goldratt (1992) defines constraint as anything that prevents the system from advancing to its goal. "Dependent events" refers to a chain of events that cannot take place until certain other events occur. "Statistical fluctuations" refers to those activities that take place at irregular intervals or the deviations in the completion of predetermined tasks that have a disruptive effect on the manufacturing process. A major cause of concern over statistical fluctuations is that prediction of a given outcome is difficult.

A manufacturing system can only produce as much as the constraint or the slowest work unit can produce, thus as all work unit reaches 100% efficiency there will be the following negative consequences:

- Considerable amount of money is tied in the form of raw and work in progress (WIP) materials not needed in the immediate future and this will cost money as investments (through purchasing materials) were made too early.
- It is possible that there will be shortages in some materials while on the other hand excess materials are accumulating.
- Long queues of WIP will build up in front of the slowest work center.
- When "Murphy"[4] strikes delays will be accumulated and it would be difficult for the system to recover as no spare capacity is available.
- Raw materials lose their value, as their flexibility is restricted as they are assembled into sub-components.
- The system will be in a vulnerable position to negotiate sales fluctuations as all capacity has been exhausted.
- Another potential downfall of cost based measures is in the area of quality. In order to reach maximum efficiency, large batches would be assigned to each work centres. If the simplest way to ensure quality is to check each batch at final assembly, then defects would be found after a particular large batch has been committed to given order. Even if there is quality check at each manufacturing process, a certain amount of materials in the large batch has already been consumed.

In addition, as responsiveness is a key competitive advantage in the 90's, to minimise the damage caused by the likely late shipment the production function will have to assign more work and expedite the manufacturing process. This in effect often requires shopfloor staff to work overtime. At this stage, the focus is no longer to make sure that there is 100% efficiency at each work centre, but to ensure on time shipment and as a result there is more cost to the company as traditionally staff working overtime are paid at premium rates.

From the above discussions it can be concluded that individual departments working in virtual isolation, each striving to meet their own efficiency standards, can have a devastating effect on downstream operations (Umble et al, 1990; Goldratt, 1992). The costs or expense incurred arising from the emphasis of localised improvement come from both short term effects (e.g. time and material resources) and long term effects (e.g. inability to negotiate sales fluctuations).

2.5 Current Reality Tree Method to Illustrating Problems with Traditional Performance Measurement

In addition to the previous discussions, a Current Reality Tree (CRT) approach was undertaken with the aim of outlining the problems associated with using traditional measures through "cause-effect-cause" mechanism or chains. The CRT method is a part of the Theory of Constraints Thinking Process application (see Chapter 3).

The Current Reality Tree (CRT) is defined as a logical structure designed to depict the state of reality as it currently exists in a given system (Dettmer, 1994). The CRT seeks cause-and-effect connections between visible indications of a system's condition and the originating causes which produce them. The Current Reality Tree is thus designed to achieve the following objectives (Dettmer, 1994):

- Identification of Undesirable Effects (UDE) from the use of traditional cost accounting measures.
- Relate UDEs through the logical chain of cause and effect to root causes.
- Identification of core problem.

The CRT is first created by listing significant and when possible all UDEs known to the system. The next step would involve connecting two related UDEs together and positioning the one that seems to lead below the one that seems to follow and

[4] Murphy is commonly referred to unpredictable events that often disturb the planned activities.

connecting them with an arrow. In addition to this, cause sufficiency[5] and additional cause factors would need to be added in a similar fashion as the first connection of two UDEs. Each different "branch" could be connected to others, which are related.

The process of creating CRT requires the development of cause-and-effect chains. These steps repeat themselves in a similar fashion until logical lateral connections present themselves. Once the CRT is completed root causes which account for large a proportion of UDEs can then be identified. In summary a CRT is used to isolate what needs changing in the existing system.

Descriptions of the effects and condition(s) that cause them are displayed in boxes. Logical connections are then made by using arrowhead lines to indicate the relationship. The CRT is read out between the entities by using "IF..THEN.." statements in the direction of the arrows. The "banana" or the semi-circular shape between two or more lines indicates the logic "AND" relationship between them.

An example of a CRT is given below:

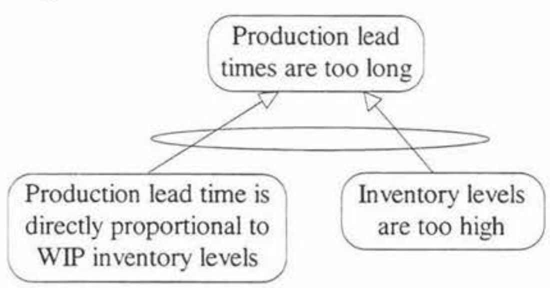

Figure 2.1: Example of a CRT.

The CRT is read as follows: "IF (Production lead time is directly proportional to WIP inventory levels) AND IF (Inventory levels are too high) THEN (production lead times are too long)". The following CRT follows the above pattern and is divided into six parts for manageable reading. Please note that in many places the CRT branches may not show detailed logical connections and "Big Jumps"[6] may appear. However, it should highlight the major lateral connections.

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[5] 'Cause Sufficiency' refers to the need for additional condition(s) to occur before the outcome or result can eventuate.

[6] "Big Jumps" refers to a chain of cause and effect that bypassed a certain element making the connection seemingly unrelated. This can occur when certain cause and effect chains are seemingly obvious that they do not need to be drawn or when no logical explanation can be presented for the missing link(s).

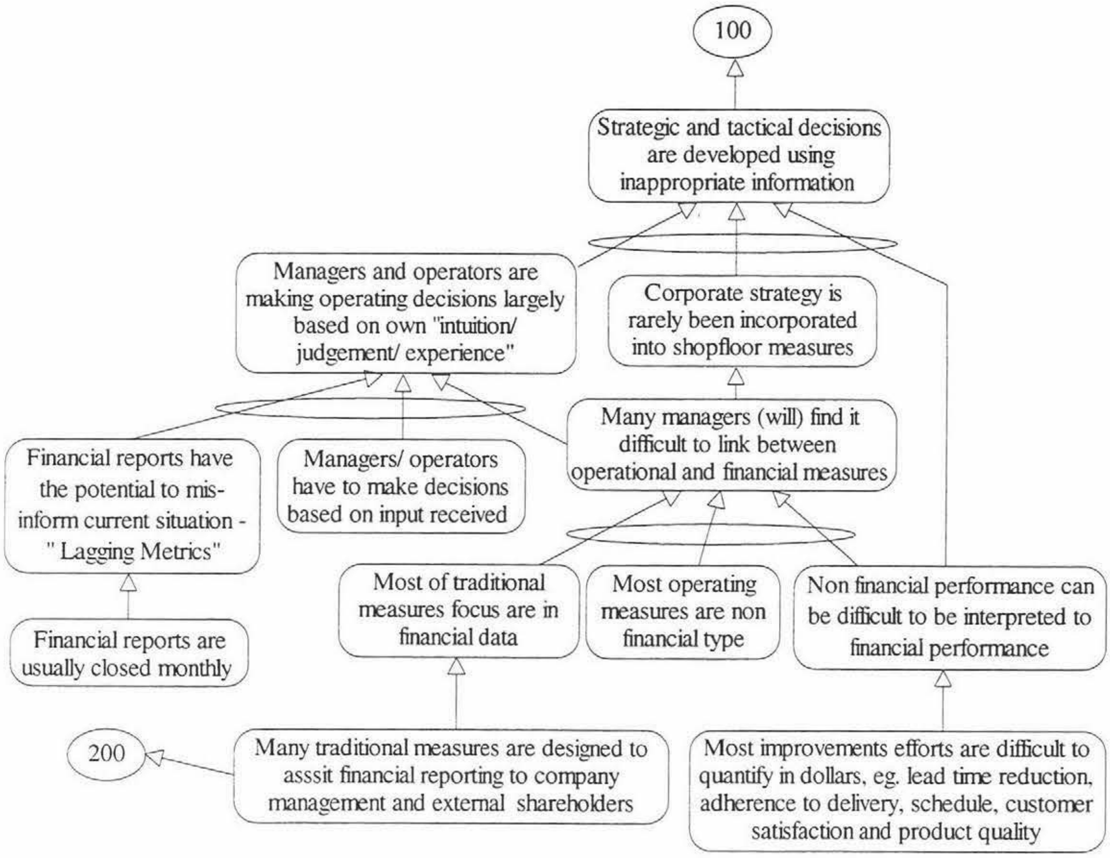

Figure 2.2: Current Reality Tree – Part 1.

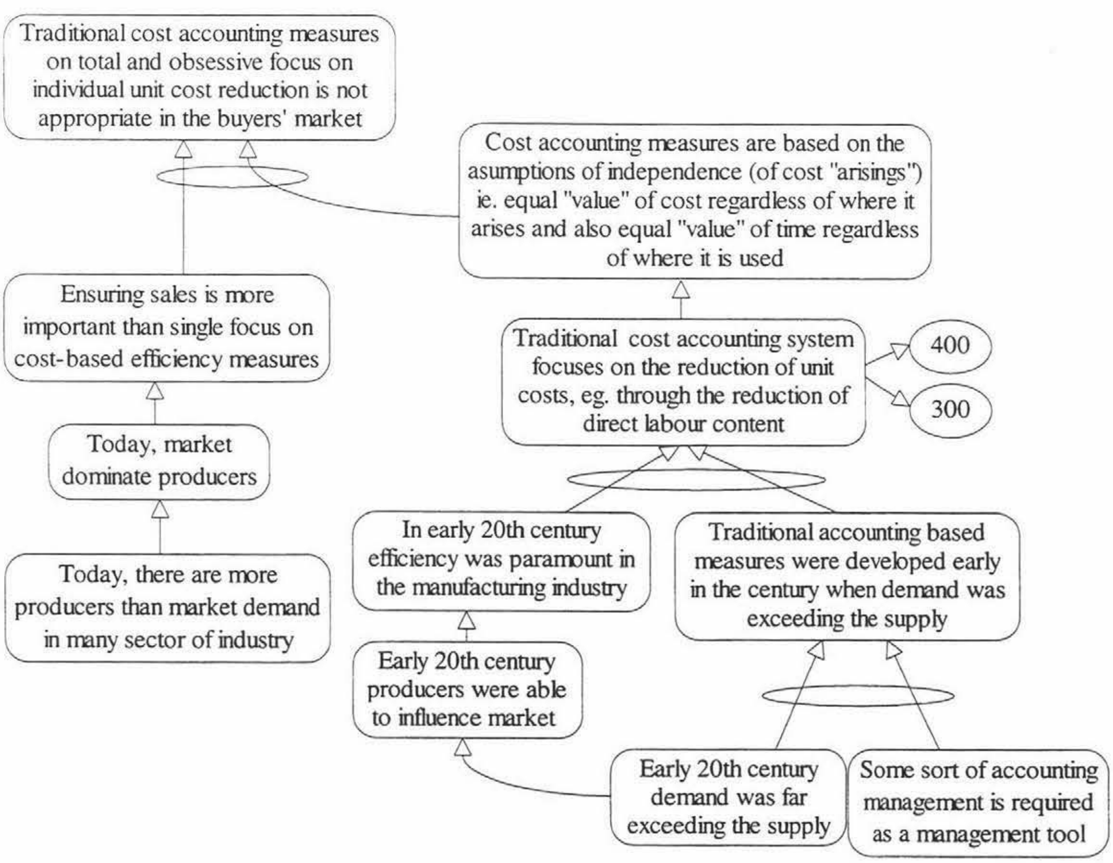

Figure 2.3: Current Reality Tree – Part 2.

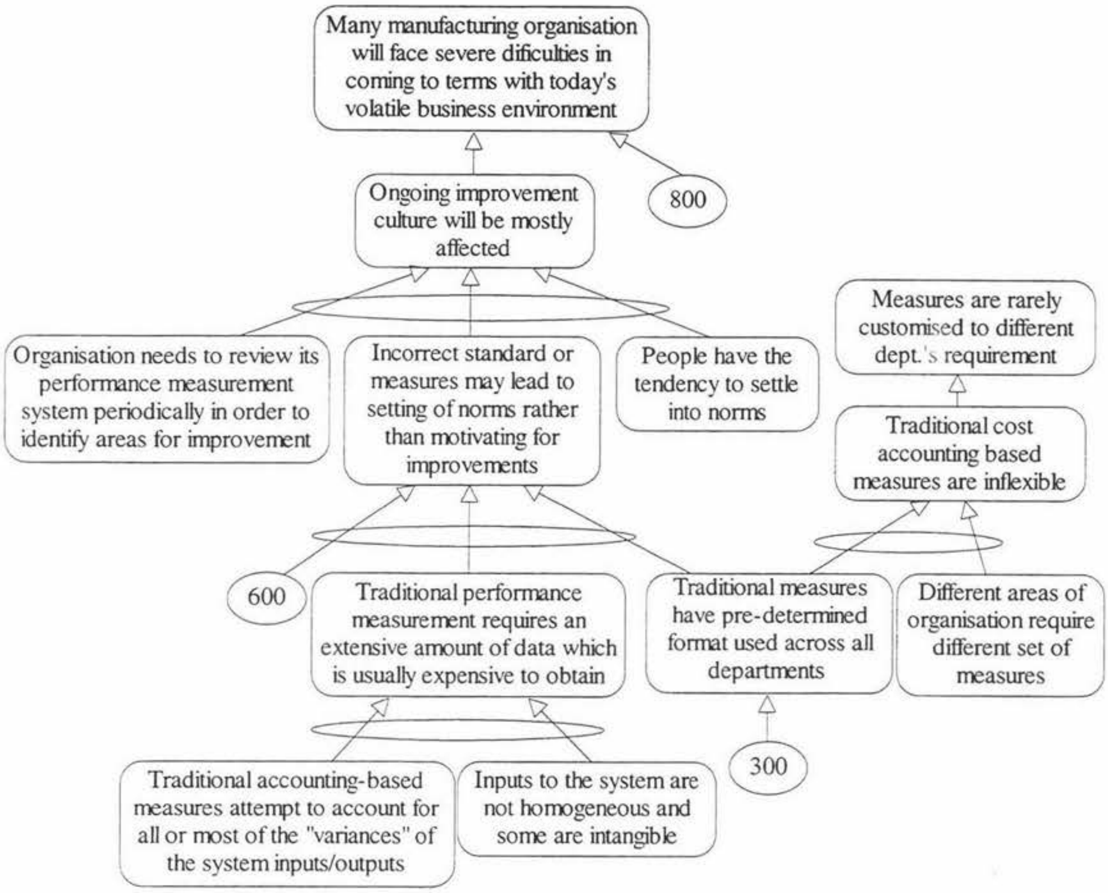

Figure 2.6: Current Reality Tree – Part 5.

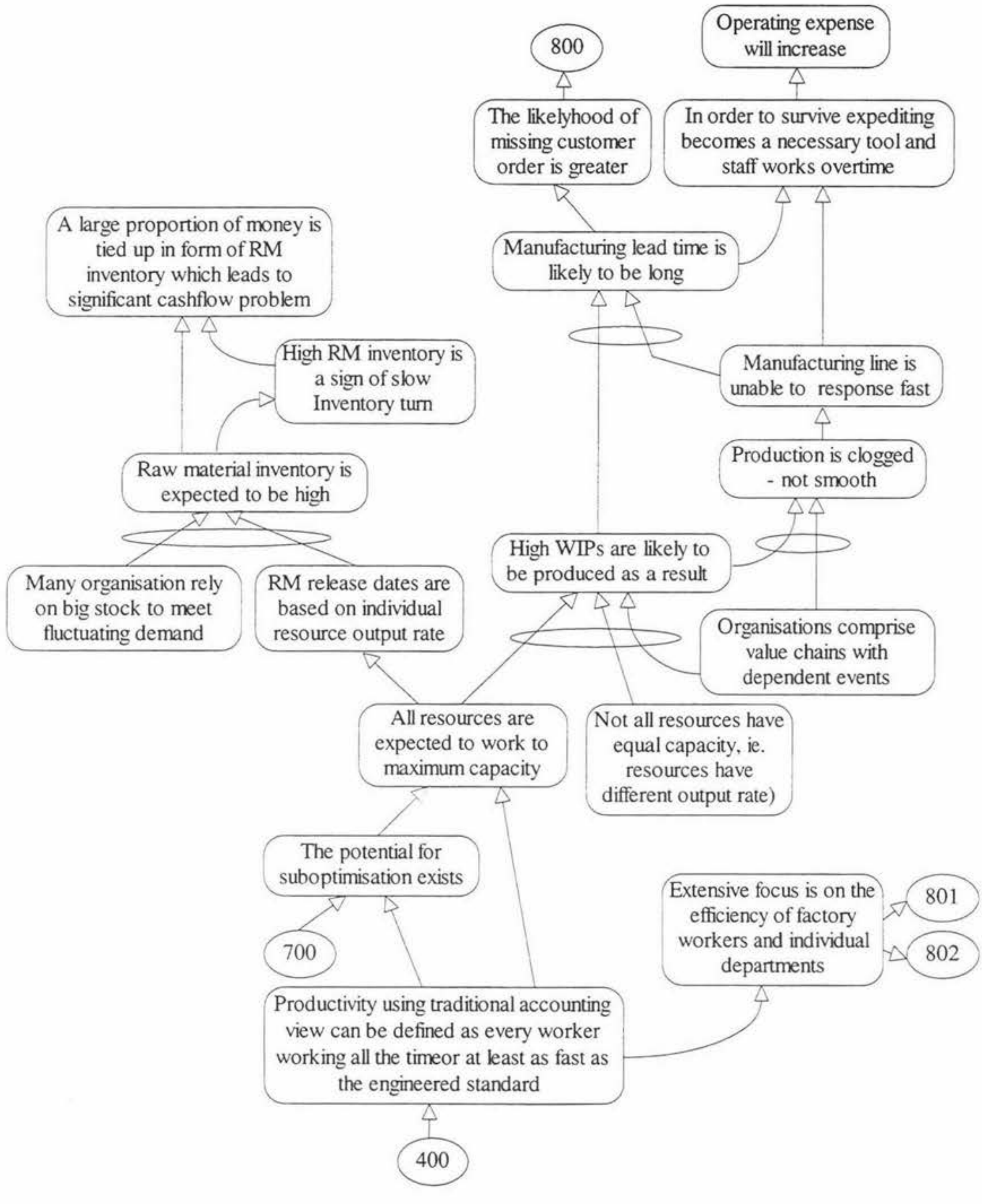

Figure 2.7: Current Reality Tree – Part 6.

2.6 Chapter Two Summary

The evolution that took place in the 20^{th} century and its effects on performance measurement was discussed. The focus on efficiency and cost was the requirements in the early 20^{th} Century. The limitations and the problems of traditional measures arose from the short-term performance focus induced by the management accounting that focuses on external reporting. Moreover, it is strongly linked to cost accounting principles applicable during the times when efficiency and controlling costs were the few key factors for ensuring profitable operations. In summary, management accounting and standard cost systems are strongly related to a company's operations management. Management accounting regularly provides key criteria for formulating manufacturing strategy and for performance evaluation purposes. In addition, due to the short-term nature of the capital market investment, the operations managers will emphasize plant financial performance. These phenomena helped induce short-term focus on operations performance. The end result is an inconsistency between the management accounting system and the long-term manufacturing focus (i.e. strategy) necessary for continued competitiveness (Fry et al, 1995; Goldratt, 1990). However, the focus on short-term performance (i.e. costs) alone is no longer applicable in today's business world where competitiveness comes from a combination of other key dimensions, e.g. excellence in engineering, quality and responsiveness. From the review of the effects of short term measures a current reality tree was drawn to help outline the problems faced from implementing traditional cost accounting principles using the cause and effect mechanism.

Chapter Three: Performance Measurement System Design

3.0 Introduction

This chapter examines key attributes in the design of a performance measurement system. It starts with a general discussion on performance measurement design attributes. This is followed by assessing the importance of measuring performance and the type of measures attached to a performance measurement system in a manufacturing firm. Selected improvement methods are discussed with the objective to identify fundamental requirements in deriving measures and managing performance measurement systems (i.e. measures and application methods).

3.2 Performance Measurement System

McNair et al (1989) cited by Lockamy et al (1994), state that the ultimate goal of a performance measurement system is to integrate the organisation's actions across various managerial levels and functions to achieve its goal. The existence of a performance measurement system helps focus company's effort on a selected range of pursuits, in the decision making process and attainment of strategic objectives that are accepted by the entire company.

Neely et al (1995) suggest that performance measurement literally means the process of quantifying action where measurement is the process of quantification and action that leads to performance that meet predetermined objectives. Measures are used to gauge past actions and the resultant data will be used to determine future actions. This process can be linked to the Planning-Organising-Leading-Controlling (POLC) cycle that formed the four functions of management (Schermerhorn, 1993). In this cycle important data such as from the measurement of progress made against planned achievements will be used to determine necessary actions to attain the company wide objectives.

In order for this cycle to function well, there is a need for a fast and reliable measurement process to enable the performance measurement function to provide meaningful data. A fast and reliable measurement process is assisted by the application of effective and efficient measures. The descriptions of these two terms that relate to the performance measurement are as follow.

Terms	Description
1. Effectiveness	Refers to how measures can help achieve predetermined objectives.
2. Efficiency	Refers to how measures improve resource utilisation to achieve predetermined objectives.

Table 3.1: Performance Measurement Effectiveness and Efficiency Terms Descriptions.

Effectiveness and efficiency suggest that performance measurement also involve both internal and external functions. Their interdependence can be illustrated from the following scenario: a firm's external function namely customer service that uses measures such as "customer focus" and "number of complaint" is supported by the firm's internal function namely production that uses measures such as "on-time delivery" and "conformance to product specification".

The followings are descriptions of other selected terms associated with performance measurement (Neely et al, 1995; Crawford et al, 1988):

Terms:	Descriptions:
1. Performance measurement	The process of quantifying the efficiency and effectiveness of an action.
2. Performance measurement system	A systematic way of evaluating the inputs, outputs, transformation, and productivity in a manufacturing or non-manufacturing operation. The system includes a performance criteria, standards and measures. The set of metrics is used to quantify both the efficiency and effectiveness of actions.
3. A performance measure	A metric used to quantify the efficiency and/or effectiveness of an action. The actual value of the performance criterion.
4. Performance criterion	The relative element (such as parts per million defects and manufacturing lead-time) used to evaluate macro- and micro-performance, long-term and short-term performance, functional performance (e.g. accounting, manufacturing, etc.) and overall performance.
5. Performance standard	The accepted satisfactory level of performance.

Table 3.2: Additional Performance Measurement Terms Descriptions.

The interaction of the above can be described in a performance measurement framework that consisted of various management levels as well as different environment within organisation. The framework roughly indicates the hierarchy and the units present in organisations. A performance measurement system can be examined at three different levels: the individual measures, the set of performance measures and their relationships with the environment in which they operate (Neely et al, 1995).

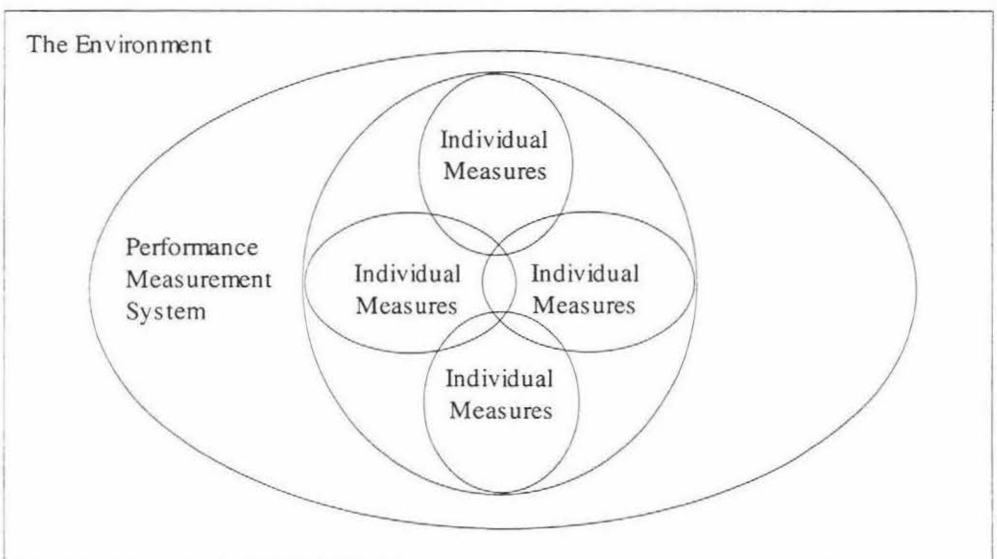

Figure 3.1: A framework for performance measurement system design – adapted from Neely et al (1995).

As Figure 3.1 shows, a performance measurement system consists of a number of individual performance measures. A collection of these individual measures and their applications in turn make up a performance measurement system. In addition, the environment surrounding the framework (e.g. external pressure and other expectations) will influence the performance measurement system. This point has also been explained in Chapter 2.

From the above it can be seen that a performance measurement system composed of performance criteria, standards, and measures that assist the planning, scheduling, monitoring, and control of resources to assist organisation achieves its objectives.

3.2 Key Benefits of Measuring Performance

Boyd et al (1997) state that performance measures are the link between individual behaviour and organisational goals. Staff used measures in a performance measurement system to identify current performance and to help formulate necessary actions to achieve company wide objectives. There are the following key benefits of measuring performance (Kaydos, 1998)[7]:

Key Benefits	Brief Descriptions[8]
1. Clear responsibilities	In order to ensure smooth operation between various functions in an organisation, tasks and responsibilities need to be assigned properly. This is to ensure that capable staff handle the required tasks and also to improve staff accountability. Measuring performance helps match staff capabilities and the type of responsibilities they could bear.
2. Strategic alignment of objectives	Performance measurement helps management to strategically align various departmental or local objectives to bring about synchronisation of all function towards achieving company-wide goal.
3. Efficient allocation of resources	From having clear responsibility and alignment of strategic objectives, management can then allocate resources efficiently so that staff can carry out their duties.
4. Better planning and forecasting	In order to enable company confronts future challenges management needs measure current performance so that they can plan and forecast better.
5. Freedom to delegate without losing control	Management should be able to delegate work appropriately without losing control using its understanding of staff responsibilities, the resources available and the targeted objectives.
6. Increased quality and productivity	Increased quality and productivity can result from such things as more autonomy, clearer responsibility and improved allocation of resources. These factors would enable staff to improve the quality of their work which is a requirement to improve productivity.
7. Recognition	One of the most powerful tools to induce appropriate behaviour is to recognised staff for their contribution towards attaining the company wide goal. This is an important step as staff need to know how their work help achieve the targeted level of performance. Staff recognition is also a form of reward.

Table 3.3: Seven Key Benefits of Performance Measurement.

[7] W. Kaydos's book titled "Operational Performance Measurement" is not yet available at the Massey University library at the time this document was produced. These seven points were shown in an internet site: www.decisiongroup.com/opm.htm and they were considered useful.

[8] These descriptions are researcher's interpretation.

Although the discussion may not cover everything that describes the need to measure performance, it has at least provided some indication on how measuring performance can be useful for organisation. The next section assessed the essential elements of performance measurement system.

3.3 Focusing Improvement Efforts using Performance Measures as the Guide

Boyd et al (1997) state that measures are used to accompany certain policies that govern activities within the system. Therefore in order to define appropriate measures major operational principles need to be defined first. This also suggests that performance measures are the link between local activities and organisation wide goal. Although it is simple to state this requirement, the process of ensuring that local activities will lead to the attainment of the company wide goal can be difficult.

In order to identify ways in which appropriate measures can be developed, focus must be placed to acknowledging what those measures need to be achieving. This can be achieved by focusing on how measures can help achieve the three major competitive edges described by Goldratt and Fox (1986) in the earlier section. This can be achieved by analysing three primary functions performed by manufacturing organisations: meeting customer requirements, utilisation of resources and ensuring sound financial results.

For a company to operate smoothly, activities of these three functions must be well synchronised by ensuring each unit's activities compliance to achievement of the company wide goal, and not just localised improvement. This means no one function can be activated and measured in isolation.

Goldratt (1992) states that the achievement of local optima does not (necessarily) lead to the achievement of the global goal. This means measurement should not instigate various units to achieve target(s) that would later induce the 'protect your rear part' behaviour. This is where departments accuse each other of trying to jeopardise each other's work.

An example that could be used to illustrate the above point is where three work centres namely Manufacturing, Sales and Purchasing are in a feud involving incoming customers' orders. The situation might see Manufacturing accusing Sales for committing too much too early (because high 'number of sales orders' would mean higher sales bonus). Completing the order as promised by Sales would be almost impossible for Manufacturing whose performance is measured by its ability to 'produce the specified quality goods at the due date promised' but whose lead-time is much longer than the delivery time promised by Sales. This in turn would create pressure on Purchasing (which is measured by its ability to provide 'cost effective' and 'discounted' purchasing) to bring in the required raw material rapidly (and probably at a premium price) from its suppliers.

The above situations simply depict how measures play an important part in inducing the right behaviour and actions to synchronise efforts to attain the targeted goal. This simply shows that measures should not be used in isolation and that attempts to do so will often result in sub-optimal outcomes (from the perspective of the overall operation of the company).

Stein (1994) states that most people would agree intuitively if given only one choice of what to improve in the three measurements Throughput should be chosen to be the most important. However, there are additional issues to consider:

- Inventory and Operating Expense have limited room for improvement, as they both cannot be reduced below the minimum level required to produce and to protect the ability of an organisation to realise Throughput.
- Attaining the goal "to make more money now and in the future" based on a program, which concentrates on a reduction of Operating Expense, would not support to sustaining growth. If the objective to achieve constant cost reduction is actually achieved then sales (lead to Throughput) would also be reduced to zero.
- If Inventory and Operating Expense exist to produce and protect the Throughput figure then understanding more about what is to be done to improve Throughput becomes a prerequisite to dealing with the other two measurements.

- Increasing Throughput is not inherently limited and therefore produces the greatest opportunity for improving the whole system. By the same token, a tremendous number of Inventory and Operating Expense can be permitted as long as the Throughput figure continuously grows at a fast enough pace.
- Concentrating on Throughput provides a tremendous leveraging effect in that since it is created by an interdependent sequence of events and the existence of a system's constraint, very few things must be improved for Throughput to increase.

The above points and their descriptions show a path to where improvement effort can be focused. This will then translate into list of things to consider when developing measures and the required plan of actions.

3.4 Types of Measures

Decision making process utilises different type of measures and they are not restricted to using certain type of measures or data as to allow enrichment of ideas for developing a working strategic plan. Santori et al (1987) state that most companies still rely primarily on conventional measures to evaluate performance and motivate people. These include both basic financial accounting and cost accounting measures such as gross margin, inventory turns and overhead variance (Goldratt, 1990). Some of these measures remain necessary and valid for assessing selected performance avenues of a company. However, some are no longer appropriate or have changed value in today's dynamic manufacturing environment (see Chapter 2 for details).

There are two major types of measures: financial and non-financial. The application of these two types of measures somehow correlate with the hierarchy of measures which roughly parallels the number of management levels (see Figure 1.1). Financial-type company wide measures such as Net Profit and Return-On-Investment are typically used at the top of the hierarchy. The interpretation of top level management measures can be found in three operational measures suggested by Goldratt (1992), they are Throughput (T), Inventory (I) and Operating Expense (OE). These are three operational measures have the capability to capture the essence of manufacturing operations. See Chapter 3.7 for more details of these three measures.

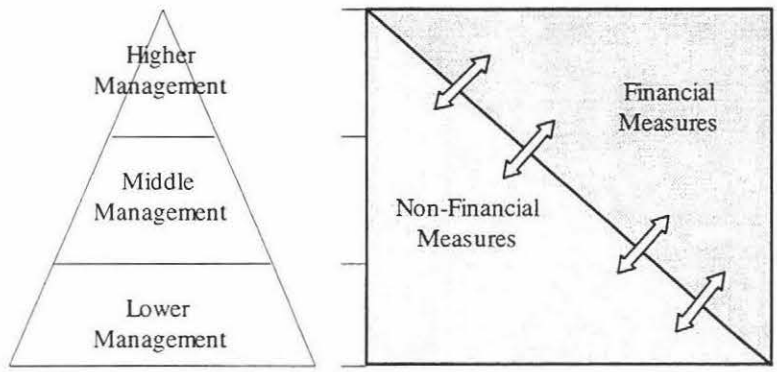

Figure 3.2: Approximate Proportion of Non Financial and Financial Measures in a Manufacturing Organisation Management Hierarchy.

Figure 3.2 shows the approximate proportion of non-financial and financial measures throughout all management levels. Both financial and non-financial measures can be used extensively but their proportion at any given management level will largely be influenced by what it is to be measured and the type of decisions to be made.

Typically, top management level mostly deals with strategic and company-wide issues using mostly financial type measures. Some of the financial measures used such as Net Profit and Return-on-Investment have significant effect to overall company performance. Other measures such as Throughput, Inventory and Operating Expense can be linked to NP and ROI (see Chapter 1). These measures have the capability to capture the breadth of the entire organisation thus they are termed the 'global' measures.

Financial measures can be used to quantify the effect of past and future operations. However, some company operations are more meaningful when they are quantified using non-financial measures, e.g. total production volume and total number of quality related problems. In addition, due to each department's function, some aspect of organisation can only be measured by either financial or non-financial measures. Some of these non-financial measures would need to taken into consideration in the strategic planning process as they have some influence long term performance.

As top management finalised its strategic plan and the targeted financial goal, the lower level management then needs to interpret them into something tangible that each local unit must carry out. This means interpreting the global measures used by the top management into various departmental measures at lower management. The measures used at departmental level or at individual level are appropriately termed 'local' measures.

Therefore from the above discussions there are the following key points in the performance measurement system: financial and non-financial, global and local measures. Some of the measures employed are also used for internal and external reporting. The next sections cover various performance measurement system designs and their associated components. The objective was to gain insight of selected authors' suggestions and to extract key criterion for suitable shopfloor performance measurement.

3.5 Kaplan and Norton's Balanced Scorecard

The balanced scorecard[9] has the objective to link corporate strategy with actual results (Kaplan et al, 1992). This is shown from its emphasis on mapping key elements of a company's performance as a whole, thus requires a balanced presentation of both relevant financial and non-financial measures of various key aspects simultaneously.

The essential thrust of the balanced scorecard is based on two fundamental prepositions: the first is "what you measure is what you get" and second is "to meet managers' requirements for a comprehensive range of performance measures in order to manage their business" (Clarke, 1997).

The balanced scorecard includes financial measures that record the results of past actions and it complements these financial measures with operational measures from other functions such as customer service and manufacturing processes (Kaplan et al, 1992). The need to combine and assess different functions simultaneously originated from the complexity of managing several functions crucial to organisation's survival.

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[9] The Balanced Scorecard, scorecard, balanced scorecard and BS terms will be used interchangeably.

The suggested framework includes four key perspectives from which to identify measures (see Figure 3.3).

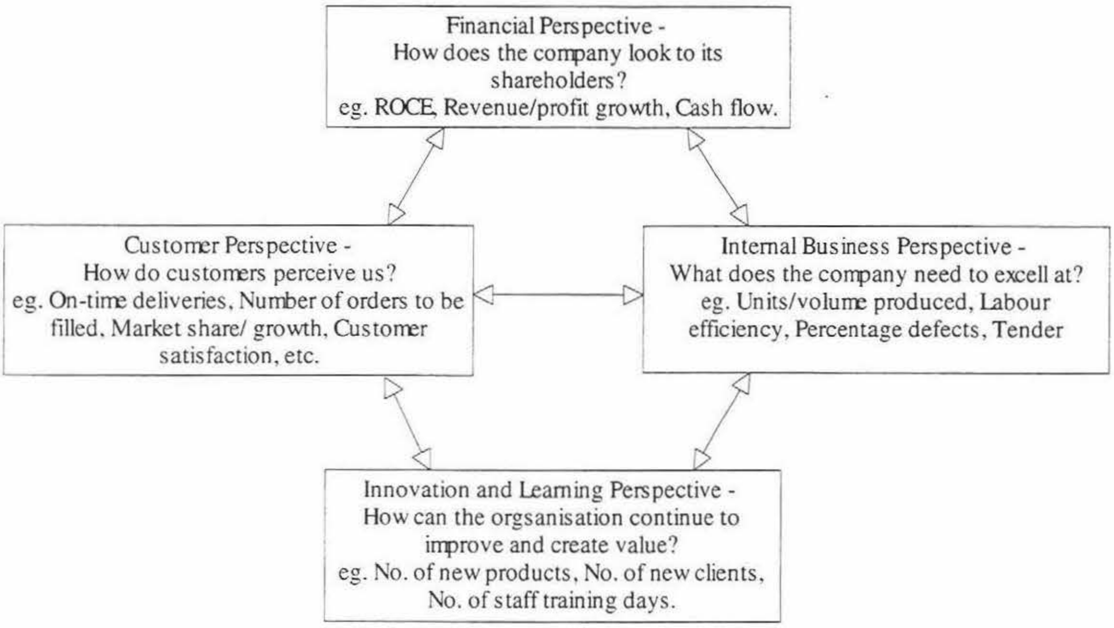

Figure 3.3: The Four Elements of the Balanced Scorecard – adapted from Clarke (1997).

The links shown in the Figure 3.3 re-enforce the need to view all elements of an organisation as a whole, not as separate entities. The structure also shows the aim of the process which is to meet customers' requirements as effectively and efficiently as possible. Descriptions of the above four perspectives and some of their related measures are described in the following section.

3.5.1 Internal Business Perspective

The internal business perspective focuses on key internal factors that deliver products and services required to maintaining business presence in the market place, such as product cycle and quality process.

Customer-based measures are important and need to be translated into measures that company must accomplish internally to meet its customers' expectations (Kaplan et al, 1992). It is logically sound that managers need to focus on those critical internal operations that enable them to satisfy customer needs.

The internal measures for the balanced scorecard should be derived from the business processes that have the greatest impact on customer satisfaction, e.g. production lead-time, quality, employee skills and productivity (Kaplan et al, 1992). In order to facilitate this a company should also attempt to identify and measure their company's core competencies and critical technologies needed to ensure survivability.

Employee involvement is thus a prerequisite to carry out internal business perspective which also aim at achieving such things as cycle time, quality, and productivity. The development of specific measures should involve employees at lower management levels to ensure staff have clear targets for actions, decisions and improvement activities. This should foster staff understanding and to encourage their commitment to the process of goal setting.

3.5.2 Innovation and Learning Perspective

The innovation and learning perspective highlights the importance of continuous improvement to meet future challenges. To ensure future successes companies must continually improve their current product(s) and processes so that their products meet customers' requirements through enhancing its most valuable asset, its employees.

Continuous improvement begins with company staff embarking on projects to improve company operation. Some means to achieve this goal is through research and development of new and better products and services, improved staff ability to produce their own improvement ideas, improved product value for money, etc.

A company's ability to innovate, improve and learn ties directly to the company's overall value and success. That is, only through the ability to meet customers' demands, to create value for customers and to improve operations continually, just to name a few, can a company move towards achieving its goals.

3.5.3 Financial Perspective

There is a need to translate improved performance into bottom-line results. If improved performance fails to be reflected in the bottom line, company managers should re-examine the basic assumptions of their strategy and mission. It must be realised that not all long-term strategies are profitable strategies.

Financial perspective represents traditional accounting measures that report the financial consequences of actions already taken. This highlights how the company appears to shareholders and other resultant measures, such as Net Profit, cashflow and Return-on-Investment.

Managers should specify how improvements in quality, cycle time, quoted lead times, delivery and new product introduction will lead to higher market share, operating margins and asset turnover or to reduced operating expenses (Kaplan et al, 1992). The challenge is to learn how to explicitly link between operations (actions taken) and finance (financial gain from actions taken).

3.5.4 Customer Perspective

The customer perspective focuses on factors that are really important to customers such as value for money, product and service quality. Without its customers, for-profit organisations simply would not exist. In order to assist in improving customer focus, many organisations have a corporate mission statement that would include customer focus perspective. However, there are other key technologies that could be used to improve company's customer focus. Some examples are customers' involvement in the design process and customer service function.

3.5.5 Advantages of the Balanced Scorecard

Kaplan et al (1992) state that the balanced scorecard has two main strengths that are as follow:

1. It summarises in one management report many of seemingly disparate elements of a company's competitive agenda, e.g. reducing response time and improving quality.
2. It prevents sub-optimisation, e.g. by forcing senior managers to consider all operational measures, the balanced scorecard lets them see whether improvement in one area may have been achieved at the expense of another.

Due to its origin from the finance function, traditional measurement system has a control bias. That is, traditional performance measurement systems specify the particular actions they want employees to take and then measure whether the employees have in fact taken those actions. In that way, the systems try to control behaviour. Such measurement systems fit with the engineering mentality of the Industrial Age.

The balanced scorecard, on the other hand, is well suited to the kind of organisation many companies are trying to achieve. The scorecard puts strategy and vision, not control, as its focus. It establishes goals but assumes that people will adopt whatever behaviour and take whatever actions are necessary to arrive at those goals. The measures are designed to pull people toward the overall vision.

By combining the financial, customer, internal process, innovation, and organisational learning perspectives, it is claimed the balanced scorecard helps managers understand many interrelationships (Kaplan et al, 1992). This understanding can help managers transcend traditional notions about functional barriers and ultimately lead to improved decision making and problem solving.

3.5.6 Limitations of the Balanced Scorecard

There are possible traps that managers must be aware of prior to embarking on decision making process using the balanced scorecard mechanism. An initial caution is for managers to be aware of the possibility of having too many or too few performance measures for assessment using the balanced scorecard structure. Being close to daily activities, managers could possibly acquire the view that everything is critical, and thus lead to the possibility of considering too many measures at the same time.

Assigning inappropriate measures to review, like any other method of performance measurement, is another possible pitfall of using this method. Managers using the balanced scorecard must be able to distinguish between those actions (or measures) that have a major influence on the organisation wide goals and other supporting actions. Although Kaplan et al (1992) describe in greater detail the requirements and the descriptions of each of the four perspectives, careful analyses are a prerequisite prior to using the scorecard system.

Although the balanced scorecard tries to prevent sub-optimisation, the structure can overshadow logical links between the various actions that shape the four perspectives. It is possible that action(s) taken in one perspective, say 'Customer', has no direct impact to improve on other perspective(s), say 'Financial' and 'Internal Business'. Incomplete analyses of the relationship between actions taken on a local area and their impact to overall performance can lead towards achieving only local improvements.

The balanced scorecard is mainly useful at the top level management; it was found that middle to lower management, could not implement the balanced scorecard without the involvement of the senior managers who have more complete picture of the company's vision and priorities (Kaplan et al, 1992). Ghalayini et al (1996) state that the structure of the balanced scorecard is primarily designed for senior managers to provide them with an overall view of performance. Thus, it is not intended for, nor suitable for factory level application on a daily basis.

In addition, the scorecard does not allow management to identify another key element to survival of examining competition explicitly (Ghalayini et al, 1996). It is still possible, however, to initially include this element in the 'Internal' and/or 'Customer' perspectives where management would be force to carefully examine competition.

3.5.7 Summary of the Balanced Scorecard

The balanced scorecard is a useful tool to highlight four important perspectives to managing organisation. The links between Financial, Customer, Internal Business, and Innovation and Learning perspectives can enable management view performance in several areas simultaneously. It can be seen as a means to synchronise improvement effort at a general level by linking actions in one area to the impacts on other areas. From this structure management can organise actions and identify local goals that would bring the organisation closer to its common goal.

However, there are various things to consider prior to using the balanced scorecard. One major problem highlighted shows that the structure of the balanced scorecard is intended mainly for middle to top management to view the different actions from the "above". The practicality of using the scorecard at lower level management was questioned, as it does not, by itself, allow easy access for developing practical and effective shopfloor measures.

Analysis of actions (to be) taken can be proved to be difficult as the scorecard structure would not allow practical cause-effect-cause connections to be developed to an adequate level. This means the structure of the balanced scorecard could overshadow cause and effect links between local/ individual actions at the four important perspectives.

It can be concluded that although the scorecard provides middle to top management with a means to view how different actions and measures can be linked together, it does not provide direct and practical method of developing specific shopfloor measures.

3.6 Lockamy and Cox's Generalised Organisational Performance Measurement System Model

Lockamy and Cox (1994) produced what they stated as a modified version of the performance measurement system developed by Cox and Blackstone (1994). This model combines together several key functions that make an entire performance measurement system.

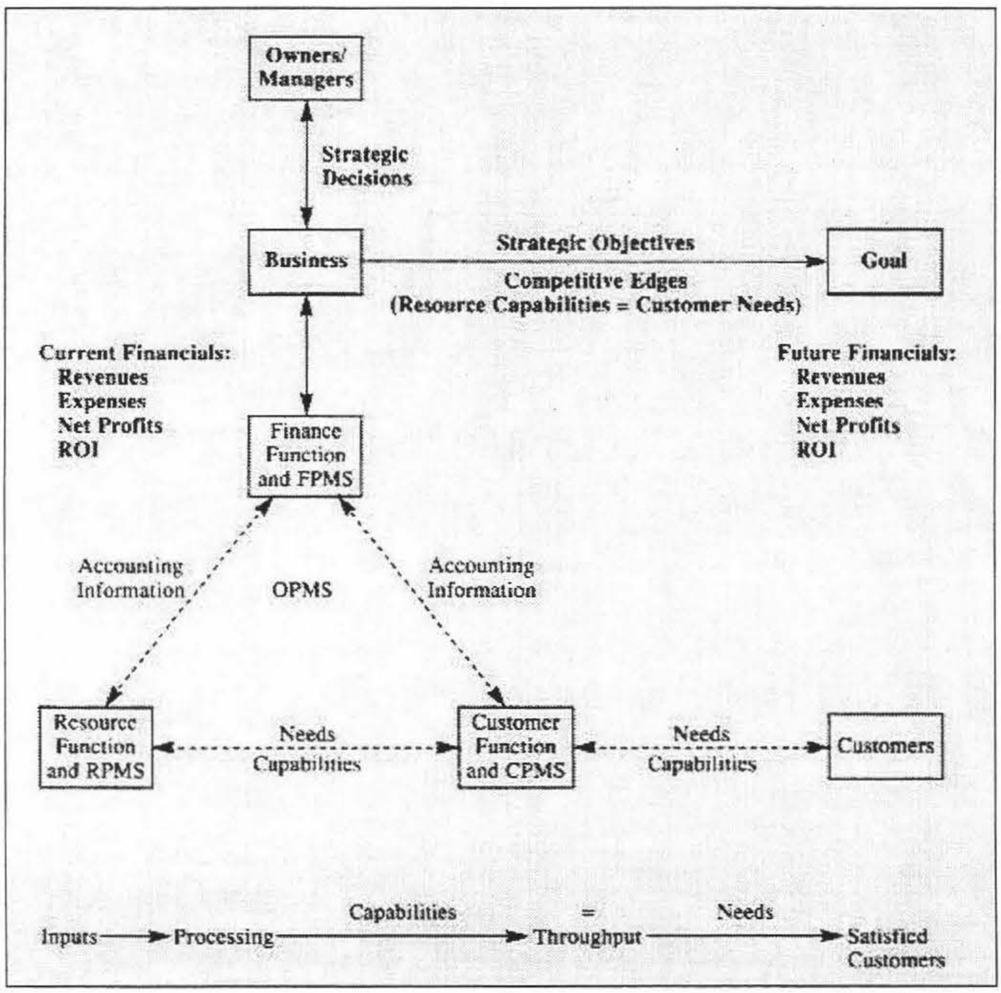

Figure 3.4: Generalised Organisational Performance Measurement System Model – adapted from Lockamy and Cox (1994).

Three functions, termed 'Finance', 'Resource' and 'Customer' functions, formed a linkage that facilitates information sharing. This triangle is formed to bring the organisation closer to the goal through fulfilling their customers requirements. The Finance function is linked to the Business function where ultimate measures such as Net Profit and Return on Investment will become some of the primary data for developing strategic decisions. All the 'links' shown in the model are aimed to provide useful communication channel between various functions in the organisation. This would be useful to involving staff to identifying the capabilities of each function to meet company wide objectives and to improve processes involved.

The model can be equated to the Balanced Scorecard where an organisation's functions are linked together to facilitate the identification of proper actions, and thus measures, to attain the company wide objectives. However, the algorithm to derive appropriate shopfloor measures has not been explicitly explained. In order to derive the measures required, Lockamy and Cox (1994) described the need to understand the Throughput World principles outlined by Goldratt's TOC prior to engaging in any decision making exercise using this model. This mean cause and effect knowledge of certain actions needs to be understood and determined prior to applying them.

The process requires determining the impact of actions taken at one function to other functions through the performance measurement systems and its links. This process coupled with further development could initiate the identification of win-win solutions needed to sustain long-term growth.

3.7 Maskell's Performance Measurement for World Class Manufacturing

Key principles outlined by Goldratt's *Theory of Constraints* and development work by Umble et al's *Synchronous Manufacturing* will help management focus the improvement effort. Their work is further supported by Maskell (1991) who states that by replacing traditional management accounting and variance reports, new and more appropriate measures can be developed to move an organisation closer to its objectives.

Among a series of suggestions by Maskell (1991), there is however a list of seven principles of performance measurement system design that can be used to derive appropriate measures. These principles are as follows:

1. Measures should be made explicit and directly related to the company wide goal and the subsequent strategies.

2. There should be a combination of financial and non-financial measures so that the significance of actions can be fully apprehended.
3. Measures will have different terms according to where they will be utilised. Different functions will require different terms for the measures.
4. Measures should be adapted to the changing circumstances. This means which measures are important will be determined by the system's constraint and that when the need changes their application and importance will also change.
5. Measures should be simple and easy to use. This means measure should not have conflicting objectives, e.g. cost based measures vs. throughput world measures.
6. Measures should be directed to stimulate continuous improvement and staff should be encouraged to use measures as tools for identifying opportunity for improvement and not as "punishment" factor.

The above descriptions suggest that shopfloor measure should be multi-dimensional to meet the various needs described in the above six points.

3.8 Srikanth's In-Sync Performance Measurement Technique

Srikanth et al (1995) offers a series of measures grouped under the In-Sync umbrella. The In-Sync measures were developed to accompany the changes in manufacturing operations that follow TOC principles. This can be seen from the inclusion of Throughput, Inventory and Operating Expense measures in the In-Sync technique to measure operational performance.

There are three groups that form the In-Sync measurement technique. They are as follows:

1. External customer focus.
2. Internal focus on making money.
3. The structure and balance in which the previous two groups are applied.

Orientation	Measure	Focusing Question
1. External	➢ Customer Satisfaction ➢ Competitive Position	• What do customers expect? • Are the customers happy? • Where is the company relative to the competition?
2. Internal	➢ Operational Performance ➢ Local Indicators	• How well is the company managing its assets? • Which specific aspect of the operation needs improvement?

Table 3.4: The Groups within In-Sync Performance Measurement – adapted from Srikanth et al (1995).

The above table shows that in order to achieve company wide objectives there are internal and external factors to consider in the development of In-Sync performance measurement. These two factors should be further defined so that necessary actions can be carried out in order to achieve effective and efficient provision of customers' requirements.

An important part of the In-Sync technique is the local indicators used to relate local processes to the achievement of overall goals. In this study, local indicators would be interpreted as shopfloor measures. The customer satisfaction, competitive position and operational performance measures provide indication on how well the business operations are performing. The measures that help evaluate how individual activities are affecting customer satisfaction, competitive position and company wide profitability are called local indicators or local measures (Srikanth et al, 1995).

3.8.1 Activity-Outcome Measure

As described in earlier in this chapter, individual or local indicators must help relate local activities to overall company-wide performance. Otherwise, as each local activity reaches its respective individual maximum potential manufacturing operations will be placed in a critical condition (see Chapter 2.4). While it is a simple and necessary requirement to insist that local indicators be tied to total system performance, this is difficult to achieve in practice (Srikanth et al, 1995). In the In-

Sync technique, these local indicators that measure the outcome of individual activity are called Activity-Outcome Measures.

3.8.2 Activity-Focusing Measure

At the individual activity level an operator must identify what aspect of one's performance has the most impact on the business. This can be linked to identifying improvement activities that will help business performance the most. The measures that help manage this specific activity so that the critical activity-outcome measure improves are called Activity-Focusing Measures (Srikanth et al, 1995).

The customer and operational measures that made up the In-Sync measurement process are aimed to provide information regarding the organisation's performance relative to activity-outcome and activity-focusing measures. Local indicators should be aimed to provide detailed and local information to assist everyone in the organisation (from top management to engineers to shopfloor operators) do the best they can and engage in relevant and focused improvement activities.

3.8.3 Constraint Measure

An essential part of the synchronous management concept is to ensuring proper management of constraints critical in the achievement of optimum company wide performance. The measures that could help management control and manage the constraints to the best advantage of the entire organisation are called Constraint Measures (Srikanth et al, 1995). For example, if materials availability were found to be the constraint then the constraint measure would be the yield for this material through the process.

Below shows a typical cycle of processes to identify constraint measures:

the synchronous approach identifies the vital activities and collects detailed information necessary to monitor these activities.

Some examples of the measures that follow the above process are as follows:

Organisational Level	**Performance Measure**	**Examples of Performance Measure**
Corporate or Division	Global In-Sync measures	Delivery, Returns, Price, etc., T, I, OE
Business Unit	In-Sync measures	Delivery, Quality, T, I, OE
Local Activity	Activity-outcome measures	Quantity, Schedule attainment, Inventory, OE

Table 3.5: Examples of types of measures appropriate for various organisational levels – adapted from Srikanth et al (1995).

In-Sync performance measurement technique advocates the company management to collect information about the constraint or the weakness area which will then be used to derive constraint measures. In addition, each employee ought to recognise how one's performance can help company wide performance.

3.9 Theory of Constraints

Dettmer (1994) describes TOC as a system's improvement philosophy. This stems from the perspective that organisation's success or failure is a function of the interactions between various internal and external processes. Goldratt (1992) states that a system is analogous to series of chains and thus the strength of each individual chain is limited by the weakest link. The weakest link can be equated as the constraint that limits the organisation ability to achieve its goal. This suggests that significant improvement results only when the weakest link or the constraint is improved.

Dettmer (1994) further describes TOC as a paradigm[10], which includes not only its concepts and guiding principles, but also its tools and applications. Spenser and Cox (1994) cited by Balderstone (1997), state that TOC consists of three main components.

[10] A paradigm can be described as a model or pattern of thinking that have the vast potential to influence behaviour.

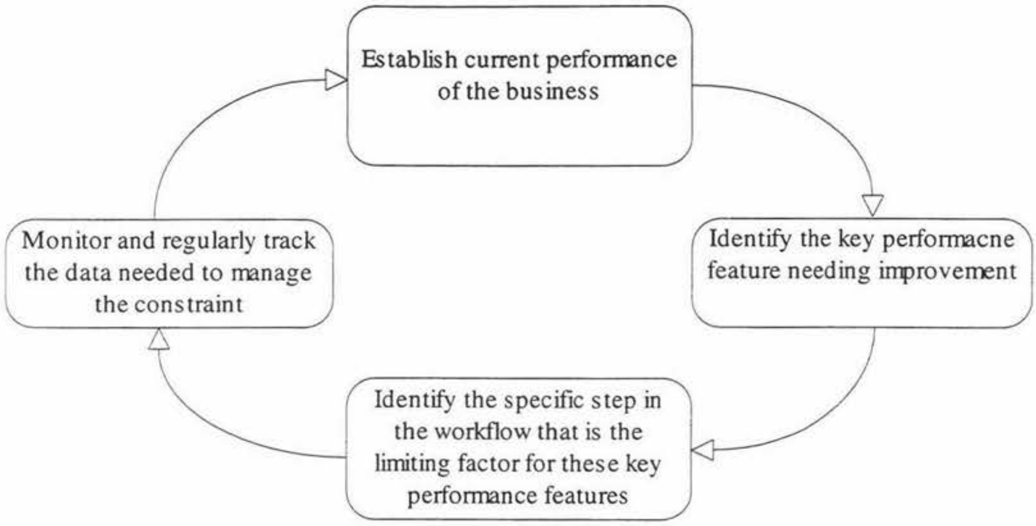

Figure 3.5: Systematic Approach to Developing Constraint Measures - adapted from Srikanth et al (1995).

Detailed definitions of constraint types and constraint improvement process are contained in Chapter 3.9 Theory of Constraint.

3.8.4 In-Sync Summary

The process of developing appropriate shopfloor or local measures starts by understanding the performance expected to be delivered by that local unit in relation to the overall company wide performance. At a local unit, the measures that help evaluate performance relative to desired results are activity-outcome measures. Measures that assist in focusing on the key aspects to ensure performance are called activity-focusing measures.

The process of developing the global In-Sync set of measures can be summarised as follows (Srikanth et al, 1995):

1. Define the appropriate set of customer and operational measures that will be used to evaluate the unit's performance. Establish targets for performance and monitor on a regular basis.
2. Optimise opportunity for achieving results by identifying and focusing on constraints. Constraint measures provide business managers with the information to manage constraints. Instead of averaging, accumulating or otherwise summarising performance of all of the myriad business activities,

Application	Descriptions
1. Production Application	The major emphasis of this subdivision is to managing project and production system. This branch includes: • "Five Focusing Steps" method to facilitate systematic ongoing improvement. • Drum-Buffer-Rope (DBR) scheduling mechanism and its associated buffer management. • A, V, T and Combination plant structure and production flow. • Distribution system design and analysis.
2. Performance Measureme nt	The TOC management accounting system is an alternative to traditional cost accounting. This has the objective to formulate a series of performance measures and necessary management accounting practices to encouraging behaviour that promotes organisation wide productivity. Included within this branch are: • Throughput (T), Inventory (I) and Operating Expense (OE) financial type operational measures. • Supporting measures at sub-system levels such as Throughput Dollar Days (TDD) and Inventory Dollar Days (IDD) to support the attainment of T, I and OE. • A TOC product mix algorithm to calculate an optimal mix of production.
3. Thinking Processes (TOC TP)	A set of problem solving tools consisting of cause-effect-cause that would allow a series/combination of actions and their outcomes to be scrutinised using "IF...THEN" mechanism. These six tools are: Current Reality Tree (CRT), Evaporating Cloud Diagram (ECD) or Conflict Resolution Diagram (CRD), Future Reality Tree (FRT), Pre-requisite Tree (PRT), Transition Tree (TRT) and the Communication Current Reality Tree (CCRT). For examples of CRTs see Chapter 2, for example FRTs see Chapter 4.

Table 3.6: TOC Applications Descriptions.

3.9.1 TOC's Ongoing Improvement Recipe: The Five Focusing Steps

The Thinking Process and other TOC applications are built around the TOC's Five Focusing Steps (FFS). These five steps help focus improvement process by concentrating on strengthening the weakest link. The Five Focusing Steps consist of the following steps:

1st Step: Identify the System's Constraint(s)

A constraint is anything that prevents a system from advancing to its goal(s). Thus, identifying the constraint is critical since it can inhibit growth in profit. In any organisation there are not many constraints, but at least a few would exist. Accumulated work-in-progress and frequently delayed due dates are signal examples of the constraint. See Chapter 3.9 for more details on the types of constraint.

2nd Step: Exploit the System's Constraint

The constraint resource effectiveness and the efficiency must be maximised as time or other resources wasted here would mean irretrievable loss. An example to exploit a constraint resource is by allocating more personnel resource to reduce machine setup time and make sure parts are there in front of the constraint resource so that it will not starve for work (effectively reducing down time).

3rd Step: Subordinate everything else to the decision made in the previous step

This step has the objective to synchronise all system activities to the tune of the constraint. This is particularly important, as to reduce the effect of fluctuations and other disturbance in the system, no other resources should be producing more than the constraint's capacity. One way to achieve this objective is by *tying* the timing of all other activities to match the slowest resource or the constraint. This means no other resources should be activated too early or too late behind the constraint schedule. Problems from ineffective synchronisation can be illustrated by the production of materials not needed in the near future, other resources producing much more parts than the constraint can consume and the constraint starving for work because parts do not arrive on time.

4th Step: Elevate the System's Constraint

This step is aimed at removing or eliminating the constraint once actions to maximise current system's performance have been taken. Examples of ways to accomplish this step are by increasing the constraint's consumption rate such as by adding its capacity (e.g. buy more resource) and by removing some workload to other resources (e.g. sub-contract).

5th Step: If a constraint has been broken in the previous steps then go back to step 1, but do not allow inertia to cause a system's constraint

The previous steps, if carried out successfully, will ensure constraint(s) to be eliminated. However, due to dependent events and statistical fluctuations there is a potential for further constraint along the system's many sections thus the cycle needs to be repeated.

The Five Focusing Steps can be used to develop applicable solutions as they allow systematic approach to solving problems that prevents managers from *fire fighting*[11]. These five steps will help understand other TOC applications such as the Drum-Buffer-Rope (DBR) scheduling mechanism that focuses on scheduling activities based on the tune of the constraint (see the following sections).

[11] Goldratt (1992) describes 'fire fighting' as an unsynchronised approach to solving problems that focused on removing the undesirable effects rather than the root cause for the undesirable effects.

3.9.2 Types of Constraint

A system's constraint is defined as anything that prevents the system from advancing to its goal and there are five constraint types with at least one constraint exists in every organisation (Goldratt, 1992).

Type of Constraint	Definitions
1. Resource Constraint	Demand placed on a resource is greater than its capacity.
2. Marketing Constraint	Market's consumption rate is less than the producer's production capacity.
3. Supplier Constraint	Demand placed on a supplier is greater than supplier's capability to deliver the required raw materials.
4. Inertia Constraint	This can be seen from the way personnel resist to change from carrying out traditional policies that are no longer appropriate.
5. Policy Constraint	When certain policy(s) prevent the system advancing to its goal.

Table 3.7: Five Types of Constraint.

However, upon closer inspection there are only two categories of constraints: physical and policy constraints, in which the latter plays a significant role to constitute the former (Goldratt, 1992). This is due to the fact that policies govern all activities within a system.

3.9.3 Theory of Constraints Performance Measurement

Goldratt (1992) suggests that the goal of any for-profit organisation would be "to make more money now and in the future". The performance for this type of company would be determined from its financial performance, and some of the most commonly used measures are Net Profit (NP) and Return on Investment (ROI). Company focus on such things as cost effective purchasing, zero defects and to be the market leader are "Necessary Conditions", sometimes the means to reach the goal, but they are not the goal (Goldratt, 1990).

Furthermore, Goldratt (1994) describes that the goal should be achieved while ensuring the attainment two other objectives. One, to protect the interests of shareholders by increasing their shares' values and two, to satisfy the interests of employees by providing a secure and satisfying environment. These are two very important factors to consider, as an organisation would not want to achieve a goal with a detrimental effect on other key elements critical for sustaining growth.

A core component of TOC performance measurement developed by Goldratt and Fox (1986, 1992) is comprised of three fundamental aspects for consideration. These are as follows:

1. How much money does the company generate?
2. How much money does the company capture?
3. How much money is required to operate the company?

The above three questions assist with the interpretation of prerequisites to achieve the goal of making money. These were then used to define financial measures to quantify profitable operation. In addition, NP and ROI are two measures that do not allow simple day to day decision making, as it would take time to determine these two measures. NP and ROI are two financial measures that would be most useful in determining company performance only after a specified period of time. Thus another set of measures are required that can be used for operational purposes and the daily decision making process.

Goldratt (1990) further defined three measures crucial to the achievement of the goal, which are synonymous with the three questions. These measures are Throughput, Inventory and Operating Expense. Their descriptions are contained in the sections following this one.

3.9.4 Throughput

Throughput (T) has been defined by Goldratt (1990) as the rate at which the system generates money through sales (of goods and/or services) over a period of time. This is measured by calculating the amount of money captured by the system or the organisation as a whole. The formula to calculate Throughput is shown below:

Throughput = Sales - Materials or Truly Variable Costs[12]

Finished goods do not translate into Throughput unless they are sold to customers outside the system. Sales revenue is a component of net profit whereas finished goods inventory is not. This means that in a multi-company group where there exist intra group trades or internal-customer[13] relationships the manufactured goods must be sold to customers outside the group.

Throughput is a financial type measure that can be understood well at the operational level and can be used in daily decision making across the organisation. The focus of Throughput also promotes behaviour that is consistent with the organisational goal of making money now and in the future.

3.9.5 Inventory

Inventory (I) has been defined by Goldratt (1990) as all the money that the system invests in purchasing things that it intends to sell. This definition includes raw materials, work in process inventory, finished goods inventory, and is contrary to the "traditional" definition in that it also includes the total assets of the organisation such as plant, land and buildings.

Inventory = all the money the system invests in purchasing things the system intends to sell

In addition to the above statement there are two collateral definitions of Inventory. The first relates to the investment made to facilitating the manufacturing process (to changing raw materials into saleable goods) such as plant and machineries. The second is the investment made to buy raw materials for making the goods. It is important to note that the latter has higher mobility than the former such as in the case

[12] Wright (1999) suggested "Truly Variable Costs" as a better term to use than "Total Variable Costs". In some case the word "Total" could mean money paid for labour. However, this is conflicting to the meaning of the word "Variable" as labour can be considered a fix cost.

[13] Internal-Customer means the relationship between one business unit to another within one group of companies. It is also the term widely used in TQM describing the need to view the relationship between various units or work centres as a chain of customers and to treat them to highest degree as it would to customers outside the organisation.

when money is generated through selling manufactured goods over short period of time. In contrast, plant and machinery form a type of Inventory that can be more difficult to be turned into Throughput. This is because plants and machinery are likely to be sold at the end of their useful life and their values depreciate over time.

Wright (1999)[14] suggests that the word "Inventory" may be replaced with "Investment" as inventory, whether they are plants or raw materials, are bought so that they can be turned into Throughput following a series of manufacturing processes. Inventory could mean more than just assets, as another side to it is liability[15]. Thus, distinctions must be made to identify when a part of Inventory is an asset or liability.

Goldratt (1990) gave an example of how distinctions can be made about classifying Inventory. Consider a purchase of oil for lubricating machines: the money paid to the vendor at the time of the purchase should not be considered as operating expense as it is still definitely an Inventory. As the oil gets used, the portion that has been used has to be removed from Inventory and re-categorised as operating expense.

Srikanth et al (1995) further state that this definition (or the process of quantifying Inventory) does not add value as the material is processed. In contrast, a common "traditional" method of valuing Inventory is to absorb labour and overhead as the material is processed thus progressively increasing its value ("Value Added" Inventory valuation). This "added-value" concept is highly misleading, as in reality no "value" has been added and it could be argued that only "damage" has been added. This is because once materials have been developed into something else, it is almost impossible to reverse the process to return them into their original state and thus flexibility is lost.

[14] Wright (1999) refers to the knowledge gained from discussions with principle supervisor Mr. AC Wright of Massey University.

[15] Goldratt, EM, *Late Night Discussions Number Five: Inventory is a Liability?*, http://www.goldratt.com/library/lnd5.htm

3.9.6 Operating Expense

Goldratt (1990) has defined operating Expense (OE) as all the money the system spends on turning inventory into throughput with the exception of inventory purchases.

Operating Expense = the money spent to convert Inventory into Throughput

Srikanth et al (1995) state that no fundamental distinction between direct labour and indirect labour is made in this definition as both should be used to assist in the conversion of Inventory into Throughput or in the flow of product to customers. The literature references also suggest that this definition, for the most part, include actual expenses. In another words, it counts real money spent as opposed to elements such as variances. In contrast, traditional costing (or standard costing) and budgeting emphasises positive or negative variance if an operation costs less or more than the budgeted figures.

3.9.7 TOC Performance Measures Advantages

Srikanth et al (1995) state that the T, I and OE overcome the direct labour myopia and the tendency for local optimisation of the traditional standard cost systems in measuring manufacturing operations.

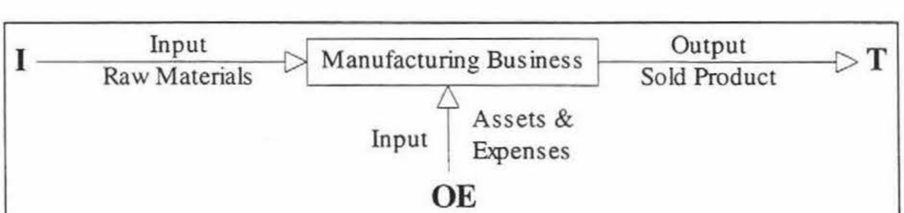

Figure 3.5: The Relationship between T, I and OE and the flow of money into and out of a system – adapted from Srikanth et al (1995).

The following formulas describe the inter-relationship between the universal financial measures such as NP and ROI and T, I and OE operational measures.

Measures	Formulas	Description
Net Profit	T – OE	It measures the amount of profit made.
Return on Investment	(T – OE)/I	It measures the percentile of return or the results of all the investments made.
Productivity Ratio	T/OE	T/OE ratio is a measure of total productivity. It represents the amount of money earned for each dollar expended. In the simple case of steady-state market conditions (where T remains steady or fixed), it is expected that good management will find ways to improve operations process improvements, inventory reductions and the like (that is to lower OE), so that T/OE will increase from year to year.
Inventory Turns	T/I	Measures the effectiveness with which inventory or material investments is converted into throughput. The higher the value of this ratio, the faster the flow of product, which in turn implies faster responsiveness, shorter production lead times and lower inventories. The ratio T/I is not linear in its behaviour with changing market conditions. As sales increases, T/I may increase at first, but as one begins to exhaust the production capacity, inventory will build up and T/I will decline.

Table 3.8: Mathematical Formulas Relating to T, I and OE.

These formulas further clarify the way in which operational measures of T, I and OE can be used to quantify ultimate for-profit organisation performance measures of NP and ROI. The formulas also suggest the way in which the goal of making money can be realised: increase Throughput while simultaneously decrease Inventory and Operating Expense.

Summary of the benefits from using T, I and OE for evaluating operational performance (Srikanth et al, 1995):

1. They link manufacturing decisions to sales.
2. They drive speed and flexibility.
3. These measures encompass all the spending under a manager's control (balance cost reduction with improvements in the competitive elements).
4. They help maintain a global orientation and discourage local optimisation.
5. These measures clearly link decisions and actions to making money.

3.9.8 Additional Operational Measures in the Theory of Constraints Framework: Brief Descriptions and A Critique

Goldratt (1988) suggests that performance to schedule is the most important measure, as any deviations from the planned schedule would result in impaired production performance. Conformance to schedule means parts should not be made too early or too late as they would jeopardize the system's balance. However, a prerequisite to this is a production function that devised its schedule with an appreciation of the system's constraint.

In order to assist on schedule performance TOC proposes two distinct types of measures that can be used at sub-systems level. First, Inventory Dollar Days (IDD) which has the aim to measure things done ahead of schedule. Second, Throughput Dollar Days (TDD) which has the aim to measure things done behind schedule. Their descriptions and shortcomings are described in the following sections.

<u>**Inventory Dollar Days (IDD)**</u>

Goldratt (1988) has defined Inventory Dollar Days to have the objective to account for excess inventories within a system. IDD is calculated by multiplying excess inventory days by the value of the unit of inventory. It could be interpreted as a measure that forces management to assess in advance the need to acquire inventory as purchasing things not needed in the immediate future could be disastrous to system's cashflow.

Goldratt (1988) further suggest that in order to establish the IDD control measurement, specific appropriate buffer will need to be defined first. The first step is to define the concept of Customer-Tolerance-Time (CTT). This is the time from when a client places an order until delivery is expected to arrive. CTT may be different from product to product and it can help determine the utilisation of resources as well as timing of the investment.

However, cited by Balderstone (1997), Noreen et al (1995) comment that the IDD measure was used at some plants visited in their study but was often dismissed as not useful as some of the measures given were too large to be calculated. A possible interpretation of this statement may be that the calculated numbers resulted in some really large figures but the measure's effectiveness in inducing the right behaviour to keep inventory as low as possible was never realised.

One possibility that may have hindered the application of the IDD measure lies with the intimately involved person (IIP) such as the production manager or the plant manager. Some of the prerequisites to a successful implementation of the IDD measure is for the IIP to be comfortable with and understand well the ramification of applying IDD in the manufacturing operations.

One of the many things to consider in applying IDD is to determining the tolerance limit for the level of inventory in the system as it can only be reduced to a certain level depending on such factors such as the availability of supply and the need to protect Throughput. In addition, contingency actions must be developed to counter the effect of reaching minimum/ maximum allowable tolerance figure for IDD.

The usefulness of IDD may not be fully realised in a system where TOC principles and DBR mechanism are applied, as it already aimed at a low inventory system of production. Therefore if DBR is applied correctly excess inventories and the costs associated with IDD may not pose any problem (Balderstone, 1997).

In a non-DBR system the IDD measure may still be applicable as it informs a widely recognised the negative impact of having too much inventory too soon. However, the buy in of the IIP into the IID measure's analysis and how it ties in with the current performance measurement system will have significant impact on the success of the IDD application.

Throughput Dollar Days (TDD)

Goldratt (1988) has defined Throughput Dollar Days as a measure that quantifies an organisation's failure to ship finished Inventory on time. TDD is computed by assigning to every late order a value equal to its throughput multiplied by the number of days the order is late, the larger the deviation from zero the tardier the order.

TDD focuses in the quantification of the magnitude of the deviation from the promised commitments to clients. The effect of, say, two orders with different value which were late for a different period could be the same due to the multiplication factor. Goldratt (1988) further state that a summation on all of the missed orders will give the unit an objective measurement of its level of performance, at any point in time, as it forces a plant to concentrate on the very late orders.

Goldratt (1988) also suggests that the measurement of TDD is not restricted to measuring just a plant's deviation. It can also be very effectively used internally, to measure the delivery performance of every production department, work centre and even the performance of other functions such as engineering and accounting.

However, cited by Balderston (1997), many researches found that although the idea sounded good in theory it was not used at any of the sites (visited by those researchers) applying TOC principles and it was dismissed as an impractical idea. This may be due to it being a 'reactive' measure that it would be difficult to ensure early compliance to schedule.

3.9.9 Drum-Buffer-Rope Scheduling

In order to gain knowledge of the importance of synchronising activities in the manufacturing organisation there needs to be an explanation of the philosophy behind synchronous manufacturing. Umble et al (1990) define synchronous manufacturing as an all-encompassing manufacturing management philosophy that includes a consistent set of principles, procedures, and techniques where every action is evaluated in terms of the common global goal of the organisation.

Synchronising activities can be facilitated by the implementation of Drum-Buffer-Rope (DBR) scheduling technique, which is the production application of the TOC. DBR concentrates on the resource constraint that determines the plant's overall output rate. DBR focuses in providing a fast delivery response and a low work in progress (WIP) inventory. The DBR mechanism utilises three components core to its operation.

Item	Definitions
1. Drum	A Master Production Schedule (MPS) that is consistent with the constraint(s) of the system.
2. Buffer	Protection of system's Throughput from statistical fluctuations through the utilisation of time buffer at strategic places, e.g. shipping buffer and assembly buffer.
3. Rope	Synchronisation of production process at each resource to the tune of the Drum.

Table 3.9: Drum-Buffer-Rope Terms Definitions.

In order to devise a good and applicable production schedule, there needs to be a consideration of the effect of system's constraints. These constraints can be any one or a combination of critical constraints such market demand, capacity and supply of raw materials (see Chapter 3.4: Type of Constraints). The series of considerations to make when deriving the basic production plan as proposed by Umble et al (1990) are as follows:

1. The proposed production plan quantities should not exceed projected market demand.
2. There must be a sufficient supply of materials available to support the production plan.
3. The proposed product flow required to support the production plan must not overload the processing capabilities of the resources.

The above considerations should result in the identification of critical factors in the production plan that both the market and the factory can support. It is also a necessary step to avoid such things as missed deliveries and sub-utilisation of resources.

Once the preliminary production plan has been established, the next step is to develop detailed schedules for the capacity constraint resources (CCRs) in the plant. This schedule is primarily derived from the system's constraint such as the market and/or other type of constraint. The CCR schedules can then be used to finalise the overall production plan and once completed the plan will be called the Master Production Schedule (MPS). The MPS will become the basis for scheduling actual (overall) shopfloor activities and the knowledge gained from the MPS can be used in devising a marketing campaign, e.g. to quoting delivery dates. The process to establishing the

MPS is referred to as the "Drum" and influences the management of other activities in the system.

The existence of statistical fluctuations in the form of production disruptions and variances will not make the actual material flow the same as in the planned flow. In order to ensure Throughput and meet the promised delivery dates, there needs to be some form of protection. The protection in this scheduling mechanism is called the "Buffer" and can be in the form of materials inventory but predominantly in the form of time. Buffers must be placed at strategic places along the firm's production system. Such a place could be found in the front of CCR or the slowest work centre and in the assembly department. The addition of Buffer will in effect increases the planned lead time from the absolute minimum required to manufacture the products by an amount sufficient to accommodate the likely disruptions.

In order to avoid further preventable disruptions the schedules of all non-CCRs will need to be synchronised to fully support the MPS, which in turn is structured to reflect and support the schedules of the CCRs. This means the planned production schedule for each work centre should be tied to the pace set by the MPS or the tune of the Drum. As non-CCRs inherently possess extra capacity, their ability to catch up following a series of disruptions makes them more agile than CCRs. Therefore, non-CCRs should not be activated to the same degree as the CCR to avoid producing more than there is demand. The synchronisation of non-CCRs is thus called the "Rope" and one function of the rope is to ensure timely release of both raw and WIP materials into and during its journey in the manufacturing system.

Some examples of successful DBR implementation can be explored in Fry et al (1991), Wu et al (1994) and Chakravorty (1996).

3.9.10 TOC Synchronisation Principles

A pre-requisite to developing shopfloor measures is the synchronisation principles extracted from the above discussions, as offered by Goldratt (1986) and further work carried out by Umble et al (1990).

1st: Balance production flow, not production capacity

The production rate should be matched to the constraint's rate of consumption as it governs Throughput. Balancing production capacity on the other hand does not guarantee smooth flow of Throughput because of such things as dependent events and statistical fluctuations. It also means materials should be released based on the constraint. Goldratt (1986) states that this can be easily formulated using the Drum-Buffer-Rope heuristic (see earlier section).

2nd: The utilisation of constraint(s) determine non-CCR utilisation

Constraint(s) determine the utilisation of resources, as resources should be utilised to satisfy the consumption capacity of the constraint. This includes the utilisation of non-Capacity Constraining Resources (non-CCR). Over activation of non-CCR will result in inventory and operating expense going up, and no actual increase in Throughput.

3rd: All resources should be "utilised" and not merely "activated"

"Activation" of resources means simply assigning work to keep "efficiencies" up at 100%. This can be disastrous to organisation operations as it does not contribute anything to maximising Throughput. 'Utilisation' of resources, on the other hand, is aimed at assigning work only when there is/are need(s) for the work centre(s) to operate. If a work centre is operated and if no Throughput is generated then it would only create waste.

4th: An hour lost at a CCR (or a constraint) is an hour lost for the entire system.

As the constraint governs all activities in the system, less than 100% operation at the constraining resources means lost of Throughput.

5th: An hour saved at a non-CCR does not have any impact in system's performance

From the previous description, CCRs govern Throughput and Inventory, thus time saved at a non-CCR does not have any affect to the entire operation.

6th: A scarce resource governs the other resources and thus the output of the system

Resource(s) with the smallest capacity will govern the completion period of customers' orders. The Drum (of DBR) will take into account both orders and production capability to develop synchronisation. This is in contrast with another method, MRP, where orders govern inventory and throughput.

7th: Transfer batch should not always equal a process batch

This is to ensure smooth uninterrupted flow of materials between work units. Transfer batch should prevent materials from sitting idle while the next work centre is waiting thus wasting valuable time.

8th: Process batches should be variable, not fixed

Process batch size should reflect the need to maintain smooth flow of product through the system and this means it will be dependent on the decision made in the schedule. A fixed process batch size would mean high inflexibility to overcome statistical fluctuations.

9th: Set the schedule by examining all the constraints simultaneously

As previously described, constraint would have significant control over the schedule as it governs Throughput rate and Inventory held. This is equivalent to solving a linear program. This approach also avoids sub-optimisation.

3.9.11 Possible Shopfloor Measures

This section has the objective to illustrate possible shopfloor measures that follow the synchronisation principles outlined. There are four possible type of resources along a manufacturing line: Bottleneck and Non-Bottleneck, Capacity Constraint Resource (CCR) and Non-Capacity Constraint Resource (defined in Table 3.11). Then, there are also three different production resources: machines, labour and materials[16]. The type of measures used depends on the type of resource and the way the resource is

[16] "Study Guide Overview and Introduction to Operations and Company Management", 43.740 Production Systems, Institute of Technology and Engineering, Massey University.

utilised. The majority of the measures shown in Table 3.11 have been derived from the Drum Buffer Rope scheduling[17].

[17] The table and the measures shown were generated during a feedback session with the chief supervisor, Mr. AC Wright and at this stage it is not yet fully developed solutions as no detailed analysis have been carried out due to time constraint.

Resource	Non-bottleneck Pre-bottleneck	Bottleneck	Non-bottleneck Post-bottleneck	CCR	Non-CCR
1. Machines	• Less than 100% Machine Utilisation • Finish Job As Soon As Possible and Stop When There Is Nothing To Do	• 100% Machine Utilisation • Minimise Downtime • Buffer Protection	• Less than 100% Machine Utilisation • Finish Job As Soon As Possible and Stop When There Is Nothing To Do	• 100% Machine Utilisation • Minimise Downtime • Buffer Protection	• Less than 100% Utilisation • Match CCR Production Volume
2. Labour	• Less Than 100% Labour Utilisation • Less Than 100% Labour Activation • Finish Job As Soon As Possible and Stop When There Is Nothing To Do	• 100% Labour Utilisation • Availability of Highly Capable Staff or "Best" Staff	• Less than 100% Labour Utilisation • Finish Job As Soon As Possible and Stop When There Is Nothing To Do	• 100% Labour Utilisation • Availability of Highly Capable Staff or "Best" Staff	• Less than 100% Labour Utilisation • Finish Job As Soon As Possible and Stop When There Is Nothing To Do
3. Materials	• Minimum to Zero Scrap • Materials Release Based On Constraint • Variable Transfer and Process Batch Sizes • Inventory Dollar Days	• Zero Scrap • 100% Yield • Materials Availability • Adequate Buffer • Variable Transfer and Process Batch Sizes • Inventory Dollar Days	• Zero Scrap • 100% Yield • Variable Transfer and Process Batch Sizes • Throughput Dollar Days	• Zero Scrap • 100% Yield • Materials Availability • Variable Transfer and Process Batch Sizes	• Minimise or Zero Scrap • 100% Yield • Variable Transfer and Process Batch Sizes

Note:
Bottleneck: Any resource whose capacity is smaller than either the proceeding or the following activities.
CCR: Any resource which if not properly scheduled and managed, is likely to cause the actual flow of product through the plant to deviate from the planned product flow.

Table 3.10: Examples of Shopfloor Measures Following the Drum-Buffer-Rope Scheduling Principles – suggestion by Wright (1999).

3.10 Performance Measurement System Design Summary

The performance measurement system covers the entire organisation from the shopfloor level to the top management level. This chapter has examined the objectives and the attributes that form a performance measurement system. This study focuses on the shopfloor management and its associated individual or local measures. Measures form an important part of management as they have critical role in guiding staff to carry out the four function of management: planning, leading, organising and controlling. This also suggests that measures should be placed in a strategic context as it influences and thus governs activities and behaviour. Measures need to be simple and explicit to allow easy determination of actions required to achieve the organisational goals. Personnel should be enthused by the measures rather than being annoyed, as they will have to use them on daily basis. Measures and the measurement process should also include forewarning function where staff will be motivated to take proper actions that help synchronise activities to prevent mismanagement of the resources available.

The selected suggestions described the importance of synchronising all organisational activities. There are a series of critical aspects which measures need to adhere to as part of overall mechanism of managing plant. Performance measurement framework as suggested by Kaplan et al (1992) and Lockamy and Cox (1994) would enable the identification of general factors affecting an organisation's performance. The application of principles outlined by Goldratt's Theory of Constraints and Maskell's seven principles of performance measurement design can further enhance the measurement system application especially the management of shopfloor activities.

Rangone (1996) states that competitive priorities have to be explicitly considered in the design of a manufacturing performance measurement system, aimed at monitoring the correct implementation of the manufacturing strategy at all levels of the manufacturing organisation structure. Hence, a manufacturing performance measurement system should be able to assess the overall level of support that each department provides to the achievement of the competitive priorities.

Theory of Constraints performance measurement suggests some robust measures that can be defined and function well at top to middle management levels. Ultimate measures of the goal of making money and three operational measures that can assist in daily decision making have been developed. Throughput, Inventory and Operating Expense can also be used to determine where improvement activities should be focused. As Throughput, Inventory and Operating Expense govern the decision making process, they will also govern almost every action in a manufacturing organisation.

TOC measures for subsystems such as Throughput Dollar Days and Inventory Dollar Days have received mix response with some indicating their difficulty in applying these measures. However, these subsystems' measures applicability and their potential should not be ignored as they bring useful perspective to the impact of plan deviation.

Throughput, Inventory and Operating Expense combined with a scheduling philosophy with an appreciation to the system's constraint could be used as the next stepping stone to develop appropriate shopfloor measures. The rationale is that smooth operation is initiated from careful planning which also implies careful scheduling. In order to ensure smooth operation appropriate measures must be developed.

Chapter Four: Criteria of Appropriate Shopfloor Measures

4.0 Introduction

This chapter examines key points outlined in the previous two chapters that would be useful in the development of appropriate shopfloor measures. The key concepts consisted mainly of the Theory of Constraints principles and a few additional inputs from other authors' suggestions. Combined they made up a list of criteria that can be used as guide when deriving shopfloor measures (i.e. local measures at the shopfloor level). The criteria are aimed to induce synchronisation of manufacturing activities so that the company wide objectives can be achieved effectively and efficiently. However, these criteria might not cover the entire requirements of developing shopfloor measures. Thus, one must exercise caution by analysing TOC synchronisation principles further.

4.1 Criteria for Developing Appropriate Shopfloor Measures

The following table contains the list of criteria and their corresponding sub-majors:

Criteria	Sub-majors
1. Direct association with company's long-term strategy.	• Direct association with the company wide goals. • Direct link to Throughput, Inventory and Operating Expense operational measures. • Appreciation of the system's constraint.
2. Assist the synchronisation of the organisation's activities.	• Shopfloor measures should assist the synchronisation process that is part of the Drum Buffer Rope scheduling. • Focus to finish work as soon as possible and avoid unnecessary production during times when there is no actual demand. • Focus to provide fast feedback to and between operators and managers.
3. Shopfloor measures can be mainly non-financial measures, but they should be quantifiable in financial terms.	• All organisational activities should be directed toward the achievement of company wide goals. As this is measured in financial terms thus non-financial measures should be quantifiable in financial terms. • Non-financial measures should assist in the development of external reports.

4. Capable to provide indication of critical success factors.	• Assist in ensuring critical manufacturing process. • Reduce "multi-tasking" – a project management concept.
5. Easy to understand and apply.	• Allow shopfloor staff to make more frequent strategic decisions locally.
6. Assist in fostering continuous improvement culture.	• The measurement process should induce continuous improvement. • Ensure appropriate work force behaviour.

Table 4.1: Criteria for Developing Appropriate Shopfloor Measures – A Proposal for Consideration.

1. Direct association with company's long-term strategy

Direct Association with the company-wide goal

Short-term gain does not necessarily lead to long-term gain as localised improvement does not necessarily lead to company-wide improvement. The goal for for-profit company should be to make more now and in the future as outlined in Chapter 3, and that everything else should be synchronised to achieve this objective. This is achieved by increasing overall company's Throughput, lowering Inventory and Operating Expense.

Direct association with the six competitive dimensions required in today's business

There are six competitive factors: quality, engineering, higher margins, lower investment per unit, shorter lead-time and responsiveness. The strategy to acquire any combination of these competitive factors may differ from one company to another depending on each company's requirements and place in the market. Performance measures must directly measure the success or failure of the company's effort to achieve any of these competitive factors and thus, the manufacturing strategy (Maskell, 1991). This means a company must identify its constraint so that it can develop necessary actions that overcome the root cause to the problems.

Application of shopfloor measures should meet T, I and OE criteria

As previously described the achievement of the goal is usually measured using traditional financial measures such as Net Profit and Return-on-Investment. The achievement of these measures is assisted by T, I and OE (see Chapter 3 for more details). In turn, shopfloor and other local measures should support the achievement of T, I and OE. A useful focusing question that might be applicable is thus: What shopfloor actions or local activities help to achieve increased T, lower I and OE? However, a prerequisite is to define the meaning of T, I and OE must be first defined for each work centre. This is due to the different names and forms of T produced, as well as I and OE consumed at each work centre.

Appreciation of the system's constraint

Every organisation has at least one constraint and relatively few constraints. Constraint management affects the type of measures used to determine activities at the lower level management. The type of constraint present in an organisation determines the type of measures to be used by its staff.

2. Adherence to the Drum Buffer Rope scheduling and synchronisation principles

Shopfloor measures should assist the synchronisation process that is part of the DBR scheduling

As described in Chapter 3, DBR permits the synchronisation of manufacturing activities. The TOC synchronisation principles that formed the DBR heuristics should enable shopfloor staff to measure both work process and outcome. The measurement of work process can be in the form comes from conformance to product or work specifications. The work outcome measures shopfloor activities, and coupled with DBR schedule, are often certain to meet the demand placed as DBR is propelled by the system's constraint(s).

Focus to finish work as soon as possible and avoid unnecessary production during times when there is no actual demand

The first part, 'finish work as soon as possible', relates to "responsiveness" and assist in achieving "short lead-time" competitive dimensions outlined in Chapter 1. Responsiveness can be defined as ability to react on timely manner to the needs of the situation, and is a prerequisite to achieving the required production lead-time. The achievement of the quoted lead-time is assisted by a well-developed schedule that takes into considerations various critical factors such as the existence of a system's constraint, dependent events and other disturbances, i.e. the DBR scheduling.

The second part, 'avoid unnecessary production', is aimed at avoiding staff increases unnecessary Inventory and possibility, unnecessary Operating Expense. As described in Chapter 4, producing more than is necessary only leads to mostly negative effects. Producing more than is necessary can be equated to producing waste and contradicts with *Muda*[18], *Mura*[19] and *Muri*[20].

During the times when demand is low shopfloor staff should not be penalised by not producing anything. The likely achievement from staff working all the time is high "labour activation" which does not add any value to company's bottom line (unless high it leads to increase in Throughput).

In addition, the Critical Chain[21] project management concept requires, among a list of requirements that staff perform like a "Roadrunner". It means staff should work as fast as possible to complete the required tasks and stop work when there is no work to do.

Measures that can be used to help achieve the desirable outcomes discussed above are, therefore, "conformance to schedule" and "conformance to specifications", (e.g. product specification). A prerequisite to installing these measures in the performance function is thus a robust DBR schedule.

However, during the low season, shopfloor staff could be encouraged to undertake "gedunken"[22] mental training aimed at finding improvement opportunities. This point has been widely advocated by TQM where staff are encouraged to find solutions to the problems themselves thus leading to process ownership and fulfillment[23]. Therefore, a possible measure to use during the low season is the "number of improvements identified". Such measure might not directly impact the company's bottom line, but there is potential for it to lead long-term performance improvement.

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[18] Muda is a Toyota TQM concept which describes the waste of waiting, motion, over-production, etc.
[19] Mura is a Toyota TQM concept which describes unevenness or irregularities that occur during production, e.g. producing more there is demand.
[20] Mura is a Toyota TQM concept which describes overburden that occurs when equipment, processes or people are pushed beyond their capacity or requirements.
[21] See Goldratt's *Critical Chain*, 1997, for more details on TOC project management concept.
[22] Goldratt (1990) describes "Gedunken", a German word that means *think*, as thinking or mental exercise that can be used to find better ways and/or doing the right things.

Focus to provide fast feedback to and between operators and managers.

Shopfloor measures and their application should assist and induce the provision of timely feedback. The feedback link is between shopfloor operators performing different tasks and between shopfloor activities and the operations managers.

3. Shopfloor measures can be mainly non-financial measures, but they should be quantifiable in financial terms

All organisational activities should be directed toward the achievement of company wide goals. Thus, non-financial measures should be quantifiable in financial terms. In general, most financial measures are not suitable to be used as decision-making tools at the shopfloor level. This is due to their irrelevancy for the nature of shopfloor activities which consist of mainly manufacturing tasks. In addition, shopfloor staff are not required to make strategic decisions for the company. However, they are required to carry out daily production operations required to achieve company wide goals. Shopfloor staff need to be able to identify how decisions made will affect T, I and OE.

Non-financial measures should assist in the development of external reports.

Local or shopfloor measures should be transformable into other types of measures (i.e. financial measures) for external reporting purposes. This is because the entire value of a company does not rest on its outright financial performance alone but also on other necessary conditions that enables the achievement of such performance. Sound operating performance is a prerequisite and this can be measured using T, I and OE. In turn these measures are achievable through accomplishing well executed schedules. Therefore, universal measures such as 'conformance to schedule', 'conformance to specifications', and '100% yield in CCR' should be adapted as they help management gauge operational capabilities.

[23] See Schermerhorn (1993) on staff motivation and personnel management.

4. Capable to provide indication of critical success factors

Assist in ensuring critical manufacturing process.

Quality process is a prerequisite to the production of quality products. One of the competitive factors required today is the provision of quality products through excellent engineering. Activity-Outcome and Activity-Focusing measures principles outlined by Srikanth et al (1995) could be used to help shopfloor staff in ensuring the achievement of quality level. In addition, constraint measures can help staff ensure that the critical operations do not get delayed. This can be achieved using buffer management and DBR plant control.

Reduce "multi-tasking" – a project management concept

In line with the Critical Chain principles, shopfloor staff must not be overloaded by carrying out "multi-tasking" activities where they are expected to perform more than one activity at once. Multi tasking has the potential to shift staff's work focus and thus might often results in longer production lead-times. Shopfloor staff should be permitted to carry out cross-functional work as it enriches both staff and the company, but staff should only be concentrating at one particular task at one time. A measure that might be useful to help shopfloor staff focus their work is the "Number of task carried out at any given time", which should be as few as possible.

5. Easy to understand and apply

Allow shopfloor staff to make more frequent strategic decisions locally

Every set of measures should be easy to understand and to be applied by shopfloor operators. This means that operators should be able to use the measures to focus their activities in accordance with the synchronisation principles, e.g. schedule attainment, on-time deliveries and quality products.

Allow shopfloor staff to make more frequent strategic decisions locally

In line with employee empowerment principles the development of specific local measures should allow shopfloor staff to make more frequent strategic decisions locally.

6. Assist in fostering continuous improvement culture

The measurement process should induce continuous improvement

Measures used should reinforce the behaviour the organisation is seeking from its employees. It is particularly important to foster a continuous improvement culture. Staff should be awarded by, not only the amount of work they did, but also how their performance and the operation affect the overall company performance.

Ensure appropriate work force behaviour

The set of measures used and/or the process of measuring a set of objectives should relate to the need to foster a continuous improvement culture. TOC's Five Focusing Steps can be used by staff as a tool to establish an on-going improvement culture, where the cycle continually repeats and assists staff to overcome whatever barrier they may face on the road to achieving the company goals. This also means that staff and/or operations should be measured on their contribution towards achieving the goal.

4.2 Shopfloor Measures Development Sequence: A Proposal for Consideration

The following steps were developed using 'define objective – define measures – define (next) objective' cycles.

1. **Define a company wide goal**
- To make money now and in the future.
2. **Define measures to be used to account for the achievement of this company wide goal**
- Net Profit, Return-On-Investment and cashflow.
3. **Define actions required to achieve the agreed goal**
- Increase Throughput while simultaneously reducing Inventory and Operating Expense.
4. **Define measures aimed to assist the above**
- Throughput, Inventory and Operating Expense.
5. **Define actions required to achieve the above measures**

- Develop a DBR schedule to plan activities
- Develop actions to accompany DBR such as 'to increase the rate of production based on the constraint', 'reduction of both unnecessary raw materials and Work-in-Progress Inventory', and 'reduce the amount of unnecessary Operating Expense'.

6. **Define measures aimed to assist the above actions at the local level**

- E.g. "Identify the constraint", "conform to product specification", "conform to schedule", "zero-defects" or "100% quality", etc.

Focusing Questions:

1. What should this/ my own function do to support the next function to achieve a company wide goal?

- In the case of manufacturing unit this would be to produce required goods on schedule.

2. What should this/ my own function do to increase organisation's Throughput, reduce the organisation's excess Inventory and reduce organisation's Operating Expense?

- In the case of manufacturing unit this would be to ensure that the required materials are present on time, to manufacture on time and to dispatch the goods to the next business unit on time.

At the individual level one must identify what aspect of one's performance has the most impact on the entire business operation. This process is equivalent to identifying the activity-outcome measure that help the firm the most. This is assisted by measures that help manage so that the critical activity-outcome measure improves are called activity-focusing measures (Srikanth et al, 1995).

4.3 A Cause and Effect Method to Analysing Performance Measures

There are many aspects of world class manufacturing and there are performance measurement methods that can be used to monitor each aspect. It is almost impossible to give equal importance and weight to all measures. Inappropriate use of measures and their numbers can become misleading and confusing instead of helpful.

Maskell (1991) states that manufacturing policies include all aspects of WCM, however each plant should focus on a limited number of key issues. The performance measurement requirements at each plant must reflect the importance of applicable world class manufacturing aspects in that plant. Performance measurement reports must therefore reflect those specific requirements.

An important factor in analysing performance measurement is to identify whether the measures move the entire work units or the plant in the direction of the goal of making money. This can be facilitated through the application of Future Reality Tree 'logic trees'[24] which is a part of the TOC Thinking Process. In this technique possible solutions or alternatives are developed with additional feasible outcome and other necessary conditions to determine whether the proposed actions would bring about the desired outcome. During the development process, negative outcome or 'negative branches' might appear as consequence of taking specific actions, thus needing some 'trimming' with additional actions that overcome the problems.

The steps to creating a Future Reality Tree are as follows[25]:

1. Write down the positive effects that are expected to result from the proposed action.
2. Write down a list of negative effects that you feel might result from taking the proposed action.
3. Connect the proposed solution with your suspected positive and negative effects by cause and effect relationships.
4. Read the negative branches from bottom up using if-then logic, scrutinising every statement and logical connection along the way, and make necessary corrections.

In this study no local or shopfloor measure was tested using the cause and effect mechanism. However, it was felt necessary to provide a background of how measures could be tested under varying degree of requirements and conditions. A decision was

[24] 'Logic Tree(s)' refers to the creation of cause and effect links that allows the identification of such things as core problems, effect of actions taken and to analyse the possible outcome of would be actions.

[25] Goldratt, EM, *The Jonah Programme*, AY Goldratt Institute, 1997.

made to look for completed work in similar subject resulted in the use of Boyd et al (1997) that have outlined a process where TOC TP can be applied to analyse the impact of applying specific measures.

Example No.1:

An example of how to construct a negative branch using efficiency as the performance measure, which is a performance measure widely used in the production department at the plant level of the Pressboard Plant.

1st step: to list positive effects that are expected to result from the use of efficiency as a performance measure, e.g. increased efficiency (what gets measured gets done), lower costs per unit of product, and increased profits.

2nd step: to list potential negative effects that might result from adopting the chosen measure - efficiency. Although negative effects of increasing efficiency may not come readily to mind, one possibility is that management will be motivated to build finished goods for which there are no orders.

3rd step: to connect the proposed action (i.e., adoption of efficiency as a performance measure for the production department) with the positive and negative effects using the cause-and-effect relationships. This is shown in Figure 4.2.

4th step: to read the branches from bottom up, scrutinising every statement and logical connection and make any necessary corrections. Branches in a cause-and-effect diagram should be read using statements in the following format: "if (the statement at the origin of an arrow), then (the statement at the end of the arrow)".

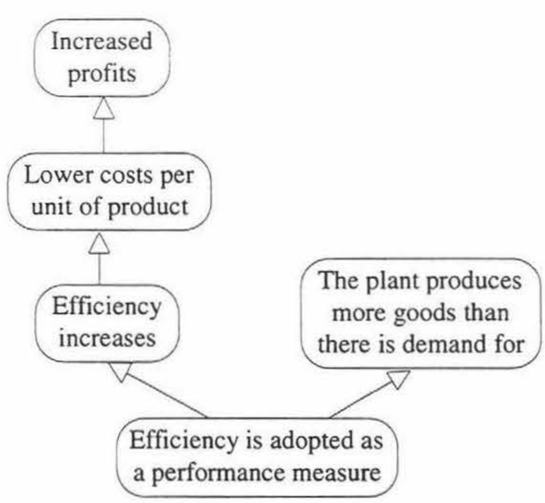

Figure 4.1: Initial connection of proposed action and expected consequences – adapted from Boyd et al (1997).

Reading Figure 4.1:

Reading up the left branch of the tree: "IF efficiency is adapted as a performance measure THEN efficiency increases". Although this may be true, other necessary conditions are needed to support the logic. Additional item to be added could be the fact that management is rewarded for maximising its performance measures.

Thus a more clear statement would be: "IF efficiency is adapted as a performance measure AND management is rewarded for maximising its performance measures THEN efficiency increases". Although this makes sense, it is still not complete because efficiency will not increase automatically because management is rewarded for increasing efficiency.

As another example, the statement of the right-hand branch of the tree is: "IF efficiency is adapted as a performance measure THEN the plant produces more goods than there is demand for". Once again, while this may be true, the logic of the statement can be improved further. This is referred in TOC TP as a "long arrow", i.e., there is a need for one or more additional statements to clarify the logic. In this case, a better cause-and-effect relationship might be: "IF efficiency is adapted as a performance measure AND management is rewarded based on maximising its performance measure THEN management will try to maximise efficiency".

This statement does not provide the way to the effect of producing more goods than there is demand for, so there is a need to add additional steps and/or entities. A logical next step might be: "IF management will try to maximise efficiency AND efficiency is defined as actual output divided by standard output THEN management will try to maximise actual output".

It is still not clear that producing more goods than there is demand for is logical negative effect of using efficiency as a performance measure. Thus another step to add in the cause-and-effect logic: "IF management will try to maximise actual output AND sometimes the market will not buy everything the plant can produce THEN the plant will at times produce more than market demands". Figure 4.2 is a cause-and-effect diagram of the above logic.

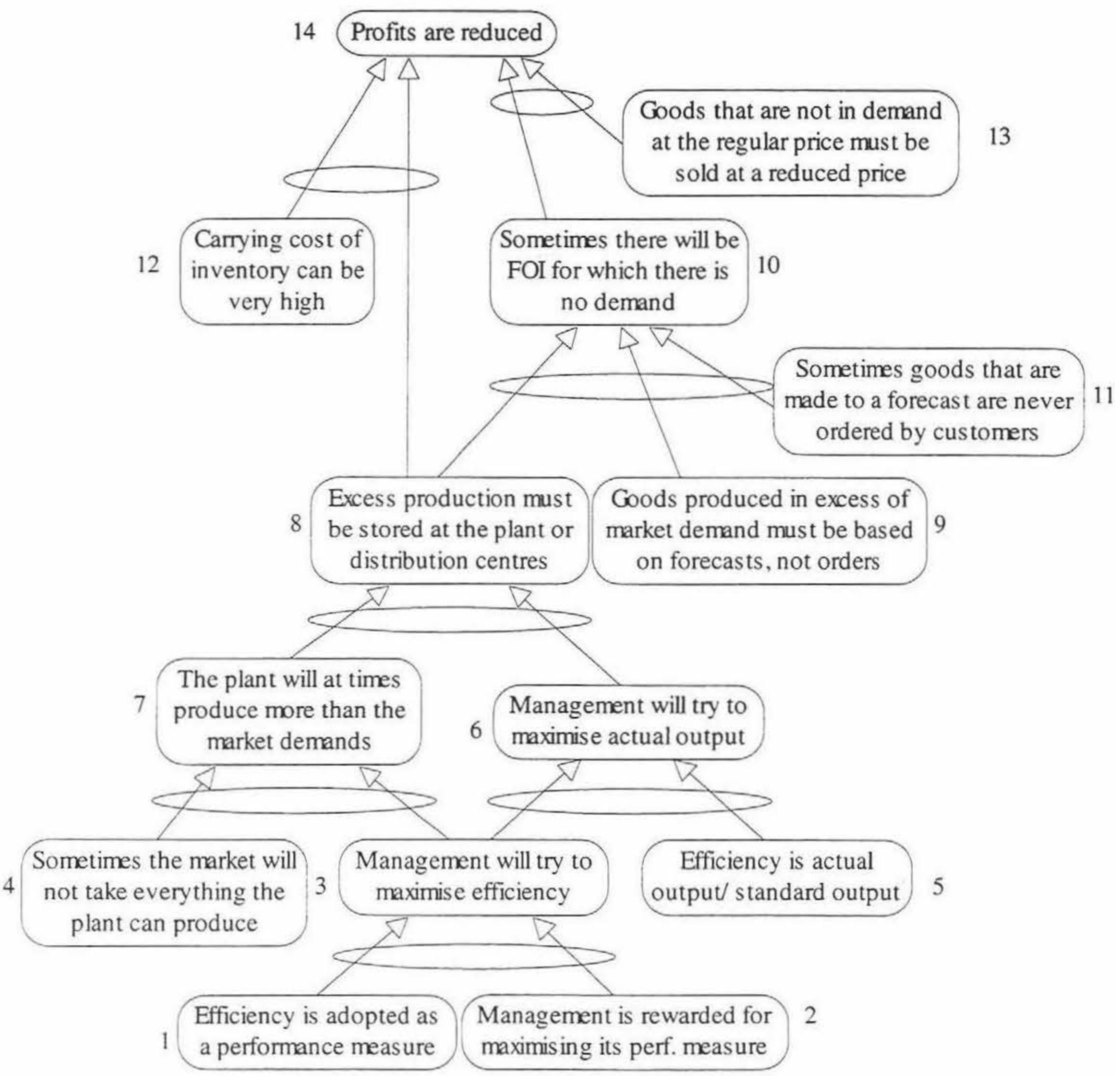

Figure 4.2: Negative Branch for Using "Efficiency" as a Performance Measure – adapted from Boyd et al (1997).

Statement 7 in Figure 4.2 is the hypothesised negative outcome of using efficiency as a performance measure. However, the negative branch has been extended beyond the effect of producing more goods than the market demands to look at the negative effect on firm profitability, which is shown in statement 14 (at the top of the tree).

The negative branch in Figure 4.2 indicates that profits will decrease if efficiency is adapted as a performance measure. A second negative branch on left-hand branch of the tree in Figure 4.1, which indicated that although increasing efficiency will lead to reduced cost per unit, it will not lead to reduced wage costs.

Negative branches can (and should) be constructed for all of the performance measures to determine whether they lead the entity being measured in the desired direction of making more money both now and in the future.

Example No. 2:
As a further example if the use of the negative branch, a negative branch is constructed below for the use of overtime as a performance measure for the production department.

1st Step: The positive effects that are expected to result from the use of overtime as a performance measure are a reduction in cost and an increase in profits.

2nd Step: The negative effects that might result from the use of overtime as a performance measure are a decrease in on-time deliveries and, depending on how labour standards are computed, less favourable labour variances.

3rd Step: The proposed solution is connected with the expected positive and negative results (see Figure 4.3).

Once again, the arrows appear to be somewhat "long" requiring intermediate steps to be inserted to clarify the logic. Beginning with the right-hand side of the tree, the negative branch in Figure 4.3 is developed. Once again, it has taken a number of intermediate steps to reach the intuitive conclusion developed in the first pass at the negative branch in Figure 4.5.

Many measures provide excellent benefits under a given set of conditions. However, most companies do not meet this given set of conditions, therefore negative consequences result.

Negative branches can be developed for basically any measure, as there are always negative and positive and impact of using particular measure. In some cases, ways to "prune" the negative branch (i.e., eliminate the negative consequences) may become apparent as the cause-and-effect relationships are diagrammed. In other cases, it will appear that the negative consequences cannot be easily avoided, and therefore it might be wiser to consider using a different performance measure that moves the department or individual towards overall goal of making more money both now and in the future.

Examples of Negative Branch Discussion:
Although it is not impossible to discuss each measure's potential, the following are brief descriptions of predicted negative effect or branches of some common used measures:

Efficiency: Efficiency is generally defined as actual output divided by standard output. Some common means of increasing efficiency are to combine batches in order to save setups, to increase machine rates, or to run an operation for longer hours. Efficiency, or the related measure utilisation, may be good performance measures at a constraint resource; however, at non-constraints (which most resources are), they can lead to producing parts for which there is no current demand. This can lead not only to increased inventory carrying costs but, more importantly, to making non-constraints unavailable when needed to support the constraint, resulting in decreased throughput for the entire plant and an increase in net income both currently and in the future. In addition to the dilution of part priorities, WIP inventory will increase and part and product lead times will increase. This increased level of WIP inventory may make it more difficult to identify quality problems and their sources. The negative branch could have been used to identify these negative consequences also.

Gradeout: This refers to the percentage of good production, and is generally a good measure as long as the overall goal of making more money is kept in mind. For example, there may be unmet demand for "seconds" at only a slightly lower price than first quality product. In this case, it may not make sense to spend a significant amount to improve the Gradeout percentage.

Cost: This is shown as a performance measure for both production and purchasing. In production, it must be remembered that most of the cost of the product is determined when the process is designed and very little is subject to management's control in the short run. A focus on cost reduction can lead to the same negative consequences shown in Figure 4.4 with respect to overtime, i.e., it is possible to save out-of-pocket costs for overtime today but end up losing customers and future profits as a result. In purchasing a focus on cost may be at the expense of quality or due date performance from vendors.

Downtime: Either total downtime or unscheduled downtime might be used as a performance measure. Measuring and reducing total downtime can lead to production for which there is no current demand. Measuring unscheduled downtime is intended to lead to an increase in preventive maintenance and a decrease in breakdowns; however, breakdowns generally only effect throughput at a constraint. Accordingly, unscheduled downtime is a better performance measure at a constraint than at non-constraint resources.

In stock: Actions in the inventory area have changed significantly with the move to Just-in-Time. Being out of stock of an item is not necessarily bad, but if not having an item in stock increases lead-time to exceed the desired customer lead-time, it should be viewed negatively. A potential negative consequence of this measure is that purchasing may protect itself by maintaining higher than necessary level of raw material inventory. A complementary measure that may help to offset this tendency is days of supply of raw material and purchased parts.

Response time: This measures the time from the date a requisition is made to issuance of a purchase order. The desired outcome is really minimisation of time from issuance of a requisition to receipt of the correct material, and there may be instances in which issuing a purchase order quickly (e.g., without exploring all options) may result in increasing total lead time for receipt of material.

On time: This is generally a good measure for the transportation function for the portion of the total lead-time for which it is responsible. In other words, transportation can only be responsible for the transit time, not the many other components of lead time that are most likely to cause an order to be late.

Complete as ordered: This can only be the responsibility of the transportation function to the extent that products are ready to be shipped.

Net Profit, ROCE, ROI: These are intended to measure whether the plant as a whole is moving in the right direction. A problem with using them to measure plant performance, however, is that they are significantly effected by inter-company transactions, including transfer prices and allocations of corporate overhead, and for this reason they may not be useful for decision making.

The above are some possible negative consequences of using these performance measures to measure plant of department performance. Developing negative branches for each measure would yield more complete and detailed lists of negative consequences for each, and should be done anytime a new performance measure is proposed. As part of the construction of the negative branch, any unique circumstances related to that facility or its environment may have to be considered.

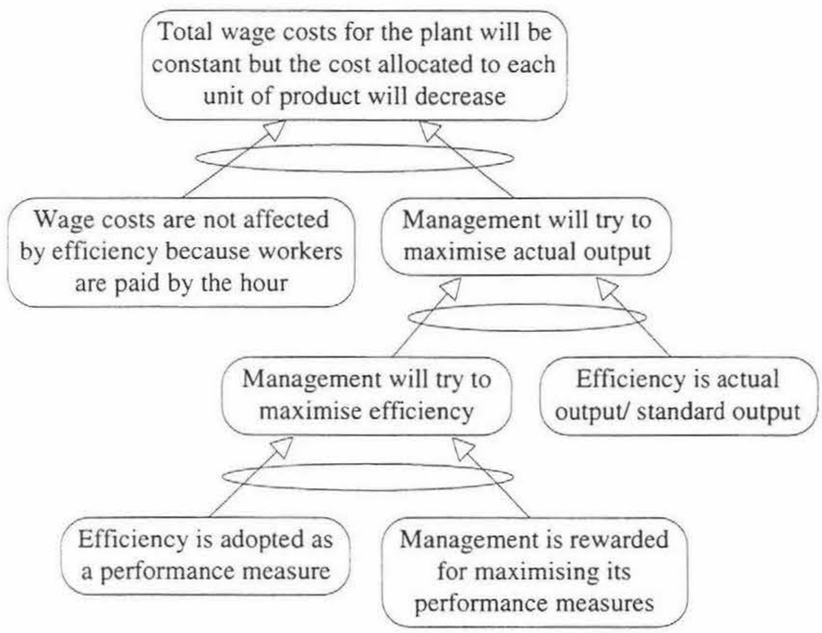

Figure 4.3: Negative Branch for Decreased Cost – adapted from Boyd et al (1997).

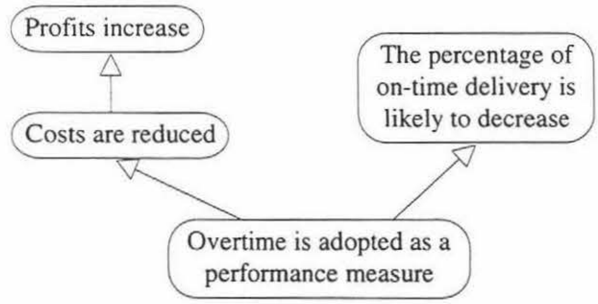

Figure 4.4: Positive and Negative Effects of Overtime – adapted from Boyd et al (1997).

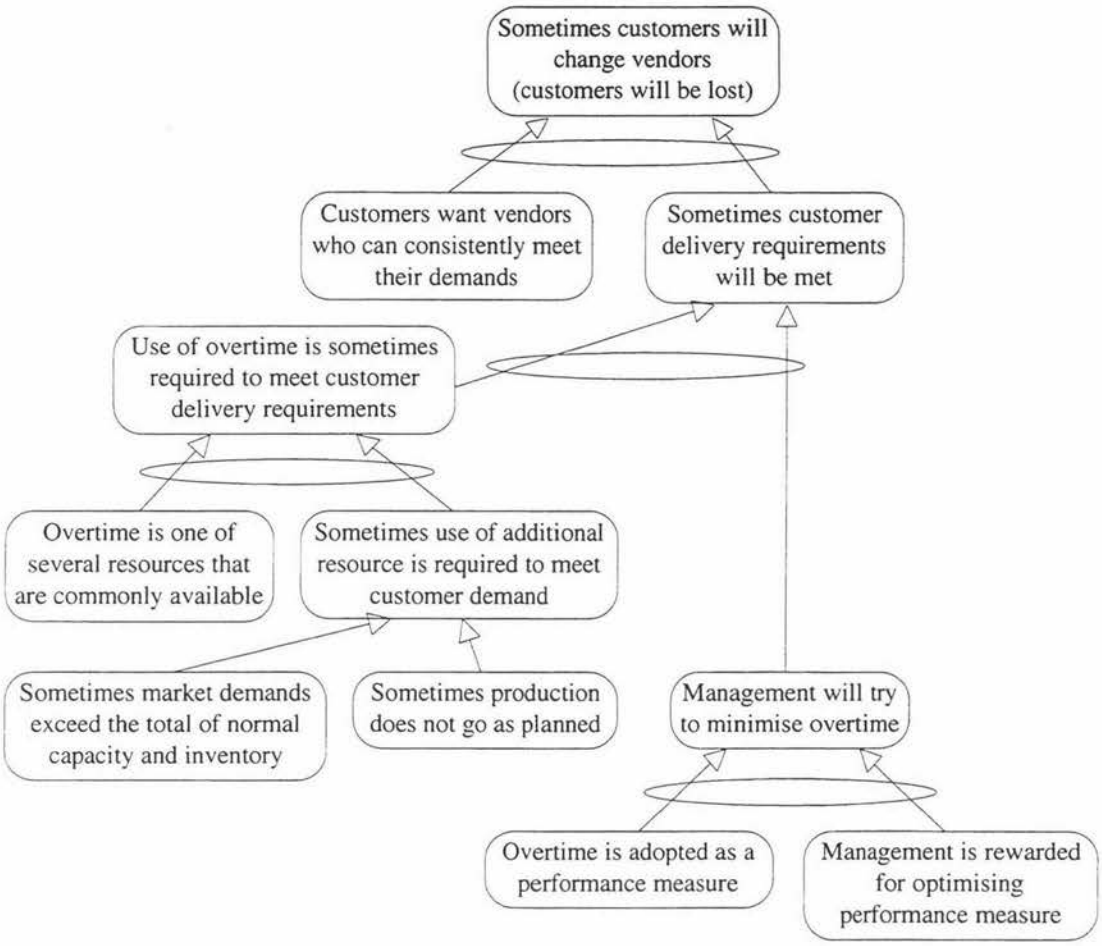

Figure 4.5 Negative Branch for Adopting "Overtime" as a Performance Measure – adapted from Boyd et al (1997).

4.3.1 Reminder

Performance measures should not be blindly chosen as almost all measures have negative consequences if they are misapplied. Analyses of the conditions, the system environment and possible negative consequences of adopting specific measures must be placed first in development of measures agenda.

The negative branch reservation part of TOC TP is helpful for analysing the conditions under which a particular measure has positive or negative consequences. An example, if a work centre is a constraint then efficiency or utilisation may be very good measures, however the same measures can lead to negative outcomes if used at non-constraints.

4.4 Chapter Four Summary

The criteria outlined in this chapter consisted mainly of the Theory of Constraints philosophies. In addition, other improvement technologies outlined in Chapter 2 and 3 were also considered. The criteria mentioned adherence to the Drum Buffer Rope scheduling which were developed using the nine synchronisation principles outlined in Chapter 3 and has been investigated to be a robust system. It consisted of a management concept that manages both constraint and non-constraint resources so that each individual resources achieve the company wide objectives effectively and efficiently. The elimination of the system's constraint as well as the reduction of its effects to the firm's performance is the focus of the synchronisation principles. The shopfloor measures should be aimed to assist the achievement of carefully developed schedule. The shopfloor measures should not be developed in isolation, as this will induce localised improvements. However, at this stage the criteria still requires further development. It is not impossible for additional key elements to be included in the criteria. One of the many ways to check the possible outcome of a particular measure application is through cause and effect mechanism that is part of the Future Reality Tree. These means, the criteria coupled with the Future Reality Tree analysis will complement each other and would help derive appropriate shopfloor measures.

Chapter Five: Survey Research Methodology

5.0 Introduction

This chapter summarises the survey research undertaken to study how New Zealand manufacturers used shopfloor performance measures. Very little has been written about the use of shopfloor performance measures and their effectiveness in the New Zealand manufacturing industry. A survey of shopfloor performance measures application was developed and carried out to gather relevant data for analyses.

5.1 Survey Research Justification

There are a number of alternatives to a survey research, which were considered. One research method considered was face to face interview. However, this method was estimated to consume a considerable amount of time and cost while the number of interview may not be adequate to gather substantial amount of data.

There is limited number of manufacturing companies that would fit the criteria of targeted companies in the Manawatu region[26]. Hence, long distance travel outside the region and often far from the main centres would be required to carry out the interviews for data collection. This was not seen as a valid option due to a time constraint and the researcher's other commitments. Therefore, to gather as much data as possible, the survey research was chosen. Survey research was also considered most appropriate to achieve the objectives of the research.

[26] Manawatu is the name of a region where Massey University Turitea campus is located.

5.2 Survey Research Objectives

The shopfloor performance measures survey of New Zealand manufacturing companies has the objective to identify and analyse the following:

1. The application of a range of pre-listed shopfloor performance measures and other company specific[27] shopfloor measures.
2. The significance of a range of common company concerns and/or production-related problems.
3. The financial performance that would indicate respondents' overall company performance and when possible, to correlate this with the use of particular types of performance measure and the problems experienced.
4. Selected production and operation tools and policies, e.g. production batch splitting and minimising the number of setup policies, and the type of scheduling methods employed.
5. Opportunities for improving operational performance using the respondents' experience and knowledge.
6. To assist New Zealand manufacturing companies, where possible, to benchmark their activities and become more aware of possible avenues for improvement with regard to the measures of shopfloor performance.
7. Reference information that would help describe respondents' companies, e.g. the number management hierarchy and the size of workforce.

5.3 Survey Research Benefits

The major benefits stemming from this survey research were the identification of Throughput and Cost World measures[28]. Investigations carried out to assess the measures' perceived level of importance and usefulness rating were helpful to gain an understanding of the operations principles applied at the shopfloor level. Results gained enabled judgment to be made on the type of improvement effort is required to bring about some competitiveness into New Zealand manufacturers. The data

[27] 'Company specific' refers to specially developed measures to meet specific company requirements.
[28] Throughput World measures refer to those measures that have the same or similar orientation as the T, I and OE operational measures concept where increasing Throughput is paramount. Whereas, Cost World measures refer to those cost accounting based measures where cost saving is paramount.

gathered should help identify any correlation between the type of measures used and the financial performance (i.e. ROI). This would help to identify the critical success factors at the shopfloor level.

The second major benefit is the identification of a list of production-related problems, and these problems' occurrence rate and financial impact. The investigation resulted in useful data for consideration when developing a suitable approach for improvement. Data gained for this section should be useful in a correlation study (with ROI data) to identify which negative factors affect financial performance the most.

Respondents' free form responses provide an insight to how operators observe the success rate of shopfloor performance measurement process currently in place. Their experiences and knowledge of current process would be useful in the development of more appropriate processes respectively.

The survey questions may alert respondents to practices that could give a competitive edge, i.e. it could be used as a self assessment tool. The questionnaire provides a prompt for managers to think through measurement issues pertinent to their current operations, to assess their performance and raises other relevant issues that they may have not considered previously. One of the many ways to achieve some objectivity for the self-assessment process was to make use of scale one (lowest) to five (highest) to measure the manager's perception on the impact of a particular measure and/or production related concern.

The data gained would describe some of the operational procedures applied in the surveyed companies. Trends and other analysis would enable to be carried in future studies. As an example of further work which may be indicated as an area for future studies, the classification of scheduling methods should enable researchers to judge for themselves opportunities for improvement in the companies surveyed.

5.4 Information Used in the Development of the Survey Questionnaire

Edwards (1986) undertook a research study which focuses on the performance measures used by management accountants for internal purposes in all types of industries, e.g. manufacturing, distribution and service. The respondents for this study are members of the National Association of Accountants, Montvale, New Jersey. Therefore, the findings from this research cannot be generalised to other manufacturing companies. Edwards's research was aimed to fulfil the wish of the Association to obtain a general observation for those performance measures that management accountants are using and to discover any other relevant information. The measures found and their descriptions suggest that standard cost accounting principles were still emphasised (see Appendix D: Traditional Manufacturing Measures). The information obtained from Edward's research was useful during the development process for this survey research. The pre-listed measures were sourced from Edward's findings as no data that would suggest the existence of particular shopfloor measures in New Zealand manufacturers existed. Details of the questionnaire are contained in Appendix A: Survey Questionnaire Form.

Other references were also looked at and analysed to help design the survey:

Author(s)	**Research Streams**	**Title or Focus**
Vokurka et al (1995)	T, C	Measuring Operating Performance: A Specific Case Study.
White (1996)	T	A Survey and Taxonomy of Strategy-related Performance Measures for Manufacturing.
New et al (1995)	T, C	Performance Measurement and the Focused Factory: Empirical Evidence.
Sinclair et al (1996)	C	Assessing the Effectiveness of Performance Measurement Systems: A Case Study.
Andersen et al (1998)	T, C	Setting Up A Performance Benchmarking Network.

Legend: T = Theoretical and conceptual framework discussion how the system should work.
C = Case study describing how the system operates in a specific firms.

Table 5.1: Selected References Discussing Performance Measurement Research.

5.5 Survey Research Design

5.5.1 Data Source

The list of target companies was obtained from the 1997 Kompass - The Authority On New Zealand Business CD-ROM[29]. This data source was loaned from the Institute of Technology and Engineering, Massey University. The Kompass CD-ROM has a setup tool that enables the selection of the companies based on specific criteria (see Chapter 5.5.3 Targeted Companies for more details). The amount of data contained, simple data classification to form a list of targeted companies and labelling has made the Kompass CD-ROM an obvious choice.

The Kompass CD-ROM manufacturer and/or distributor has kindly provided 1000 free print credits that permitted the transfer of data to Microsoft Word for labeling purpose[30]. This would otherwise cost approximately $100 plus GST[31].

Another database, the New Zealand UBD (New Zealand Universal Business Directory) CD-ROM was assessed prior to using the Kompass CD-ROM. It contains the addresses of more than 150,000 companies operating in New Zealand. However, it does not have the same setup tools that would allow straightforward classification of companies and was thus considered inappropriate.

5.5.2 Targeted Respondents

The survey pack was targeted at senior management who had a satisfactory knowledge of the company's operations and the application of performance measures (see Appendix C: Introductory Letter for details). The introductory letter (and the survey questionnaire) was addressed to senior member of the management with a position title such as 'Production Manager', 'Managing Director', 'Operations Manager' or 'General Manager'.

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[29] Kompass - The Authority On New Zealand Business CD-ROM from herein will be referred as the Kompass CD-ROM, Kompass database or Kompass.

[30] A telephone conversation with a sales representative of the Kompass CD-ROM confirmed the provision of these free print credits as they are used for academic research purpose. The contact address of the manufacturer/distributor is shown on the CD-ROM's protective casing.

[31] GST is an abbreviation for Government Service Tax imposed by the New Zealand Government at 12.5%.

5.5.3 Targeted Companies

The criteria for target companies are as follows:

1. Top 300 New Zealand manufacturing companies as listed in the Kompass CD-ROM. The KOMPASS CD-ROM manufacturer did not make details of the selection criteria used to derive this list public.
2. Manufacturers of both domestic and export goods.
3. Medium to large sized companies (i.e. companies that employ more than 25 personnel).

300 company managers were sent survey and this was not seen as an exceedingly large number given the nature of the survey research that has the potential to net a low response. In order to ensure some validity in the statistical analysis the research aimed at a minimum of 30% response rate (i.e. 90 companies).

Manufacturers of both domestic and export goods tend to produce higher volumes and employ higher numbers of employees. In addition, due to worldwide competition these companies are likely to impose some international standards. This means they are likely to contribute significant data as, in order to compete internationally, they need to apply some of the latest and modern technologies. These companies' experiences would provide some useful hints on how measures should be adapted and developed to bring about the desired results.

The *medium* size companies scale for the New Zealand economy may be different from that of other countries. The New Zealand Statistics Department[32] uses a classification which is as follows: "0 to 5", "6 to 9", "10 to 49", "50 to 100", "100 or more" employees. However, a different classification was used for this survey as this survey aimed at "medium to large sized companies that employ more than 25 personnel". Although these two classifications are different, the classification used in this research included middle to the highest point as described by the New Zealand Statistics' classification and was therefore considered to be suitable for targeted companies criteria.

[32] New Zealand Statistics is a New Zealand government agency that collects and analyses important statistical data.

The rationale for the above criteria is that medium to large sized companies are likely to utilise some form of performance measurement system. Their experiences in using particular types of shopfloor performance measurement system will greatly assist to identify opportunity for improvements.

5.5.4 Methods to Ensuring Adequate Response Rate

Past experiences of other researchers who carries out survey research using mailed questionnaires indicates that 15 to 30% response can be considered as "normal" [33]. Careful consideration was thus given trying to ensure the highest possible return rate, which are as follows:

- Actual names of the persons holding the targeted positions were included which was intended to stimulate interest.
- Careful choice of survey question sequence.
- The provision of self addressed freepost return envelopes.
- Phone calls to approximately fifty (50) major companies with the objective of tracking progress following a follow up on non-respondents.

5.6 Survey Research Process

The survey instruments were designed in collaboration with a group of Institute of Technology and Engineering lecturers. The five-member panel comprised quality, statistics, manufacturing systems and production operations experts who have acquired comprehensive survey research experiences throughout their professional careers[34].

The development process took approximately eight (8) weeks before the final version was agreed. The development of the questionnaire involved the *action-learning* process, whereby the researcher submitted draft version of the survey instruments to the development team in three phases[35].

[33] Conversations with both 1st and 2nd project supervisors with vast experience in similar projects suggested that 30% response could be considered as 'good' and it was hoped that it would help to statistically validate the results.
[34] See Acknowledgement at the beginning of this thesis for more details.
[35] 'Action Learning' can be considered as the learning process that uses the results gained from taking specific actions.

The final version and description of the proposed research were then submitted to the Massey University Human Ethics Committee for approval. The process took some time as the committee only meets once a month and hence the feedback letter was not received until five weeks after the proposal was submitted. Some minor changes to the survey arose from the suggestions made in this letter.

Once the required modifications were completed, the survey proposal was given written permission and actual survey process began (see Appendix E: Letter of Approval from the Massey University Human Ethics Committee to Undertake the Survey Research).

Details of the survey process are outlined in Figure 5.1. The survey research task included mailing out survey packs to the targeted companies and progress tracking.

The following flowchart shows major steps taken to carry out the survey research.

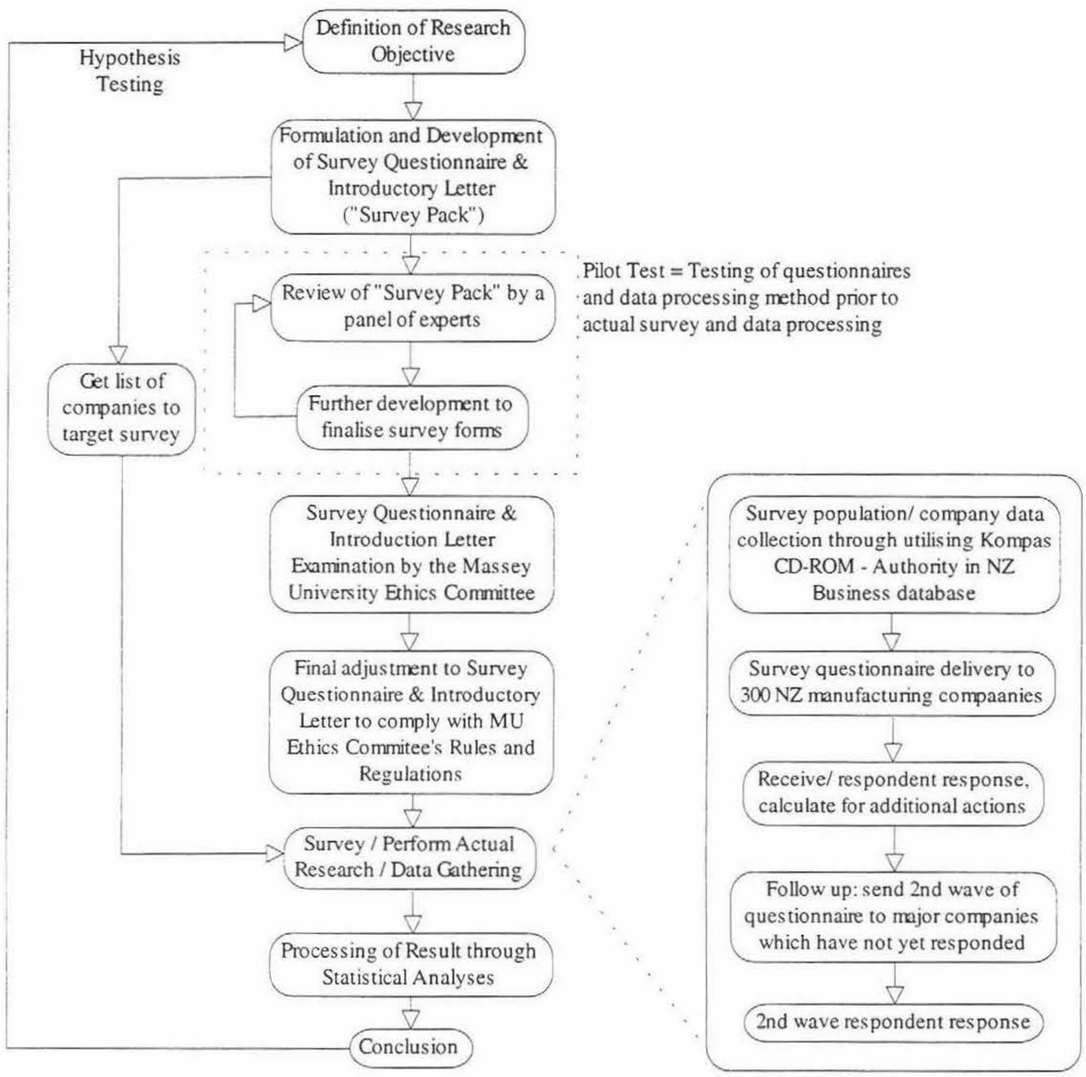


Figure 5.1: The Shopfloor Performance Measures Survey of New Zealand Manufacturing Companies Flow-chart.

5.7 Survey Research Instruments Design Considerations

The main considerations in the design of the survey instruments were:

1. To design a questionnaire that could be administered to a large number of respondents from different plant types and manufacturing categories.
2. To design a research instrument to achieve research objectives and to diagnose the application of shopfloor performance measurement.
3. To design a research instrument that could be used by the respondents to identify areas for improvement.

There are two main factors to consider for the survey questionnaire: *plant type* and *manufacturing category*. Stein (1997) describes that the inherent differences between each plant type made their management unique and this can be seen from the different policies and measures required to ensure smooth manufacturing processes. Therefore, the significance of specific manufacturing processes needs to be comprehended to determine the likely problems and their solutions.

Each plant type and manufacturing category has its own characteristics and it is believed that these have significant influence on the performance measures used. To test these theories against the actual practices the following hypotheses have been formulated and they will be tested using the survey results analysis.

Hypothesis:	**Definitions:**
A. Null Hypothesis, H_0	1. There is correlation between the measures used and the type of plant. 2. There is correlation between the production-related problems to the type of plant.
B. Alternative Hypothesis, H_1	1. There is no correlation between the measures used and the type of plant. 2. There is no correlation between the production-related problems and the type of plant.

Table 5.2: Hypotheses Definitions.

5.7.1 Plant Type

The first factor is *Plant Type* which refers to how raw materials flow through the manufacturing process. Umble et al (1990) define four types of plant logistics and process flow: A, V, T and Combination plant. Each of these plants has distinctive characteristics that influence its management which will be explained in following sections. The importance of plant types cannot be isolated from this survey research, as measures must be tailored to suit the need of each plant.

The letters A, V and T describe the flow of the products through the manufacturing process. However, there is another plant type introduced in the questionnaire and it is called the I-plant where there is a single flow of assembly processes. Umble et al (1990) or Stein (1997) never explicitly discussed this plant type. The researcher wished to identify the existence of such plant in the New Zealand manufacturing industry since experience suggest that majority of New Zealand manufacturers are small in size and many produce only specific products. Thus, its existence in the industry and the subsequent results may become something worth considering for future research.

The following sections aimed to further describe individual plant types and their characteristics. The information contained was heavily borrowed from Stein (1997).

Type A-plant

The A-Plant is characterised by a large number of converging operations where there is significantly smaller number of final products than the originated from a wide variety of raw materials. Sub-assemblies are usually purpose built for final products and the technology involved assembly operations tends to be highly flexible.

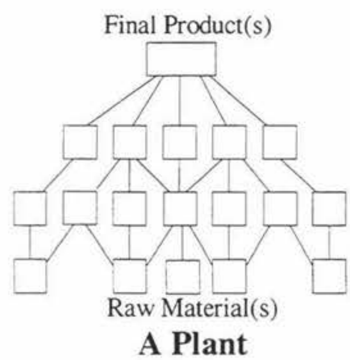


Figure 5.2: Type A Plant Configuration.

Under traditional (cost-based) management practices the tendency is to misallocate resource time in an attempt to maximise efficiency and utilisation figures. Large batches are assigned to keep the measurements high often resulting in a poor component mix and a constant shortage of the right parts in assembly operations. Transfer batches are usually large matching the size of the assigned batch size. These large batches move in "waves" throughout the plant causing temporary bottlenecks to wander from resource to resource. The result of this operation is machines may be under-utilised one minute and over utilised the next.

Since the flow of material is constantly out of balance in a plant practicing the local maxima principle, overtime is used to "catch up" so the shipments can be made on time. The resulting impact of constant expediting on the quality system is disastrous. Large batches will result in an increase in Inventory (both raw material and work-in-process) and a reduction in visibility of process control. Both process and thus product quality will tend to decrease. Because of the poor material availability and constant expediting there is often a high amount of pressure exerted to pass marginal material as acceptable to meet scheduled due dates.

Type V-plant
V-Plants are characterised by constantly diverging operations with a small number of raw material items being converted into a large number of end items using specialised equipment.

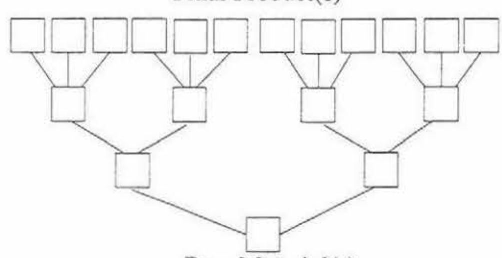


Figure 5.3: Type V Plant Configuration.

Each diverging point in the process is an opportunity to misallocate material and this is a problem feature for the V-Plant. Under the traditional (cost-based) approach expensive equipment must be utilised constantly to absorb overhead and to ensure that adequate value is received. Set-ups are usually extensive so to raise efficiency batch sizes will be kept large.

Unfortunately, this results in material being taken from diverging operations in quantities larger than required. One leg of divergence will be unable to perform because another leg received material which should have gone to it. If material is misallocated prior to the constraint it results in a misutilisation of constraint time. Material processed on the constraint, which is not dedicated to creating Throughput results in a decline in ROI. Material misallocated after the constraint will result in an increase in finished goods of products for which there is no demand.

As the result of the above customer service levels will be poor. To offset for constantly being out of stock, finished goods inventories will be raised even higher through an attempt to forecast. Like the A-Plant, large batches increase Inventory and reduce visibility while quality suffers. The solution is much the same as that for the A-Plant and that is to synchronise product flows with the systems constraints and customer demand. Lot sizes should be matched to requirements for creating Throughput, while minimising Inventory and Operating Expense.

Type T-plant
T-Plant is characterised by a relatively low number of common raw material and component parts optioned into a large number of end items. To support a requirement for meeting short lead time demand a two-level master schedule is normally used where common components are schedule and stored just prior to

final assembly via forecast and then assembled to order based on specific customer configuration.

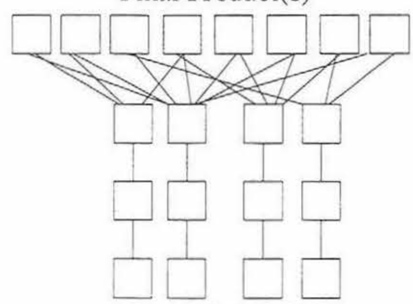


Figure 5.4: Type T Plant Configuration.

The T-Plant distinguishes itself from A-Plant in that A-Plant is dominated by the convergence interaction, whereas the T-Plant is dominated by the divergence which occurs just prior to final assembly. Prior to this stage there are no converging or diverging operations. Raw material is processed without being assembled or converted into more than one part, so the number of raw material and sub-assembly component quantities will be the same.

Since diverging operations provide the potential for misallocation of material, inventories at final assembly will not match customer demand. Customer service levels will be low. Under traditional management strategies better equipment utilisation means larger lot sizes resulting in the same wave effect seen in A-Plants, exacerbating the out of balance conditions in inventories while extending lead times and reducing visibility. Quality suffers. Attempts at "modernising" the plant and bringing in "new", "more efficient" and "cost effective" equipment may result in less flexibility and an even bigger desire to maximise equipment utilisation, making the problem even worse.

Type I-plant

The I plant is not commonly discussed in the literature as many researchers do not believe that an I plant type really exists. This is because the T or a slim version of the A plant types would justify the process flow quite well. Wright (1999) reckons that a 'true' I plant is more likely to be like the base of the T plant (without the T) and would typify some service where the customer flows through successive steps. An I plant as drawn below is more likely to be a V on an A or T on an A.

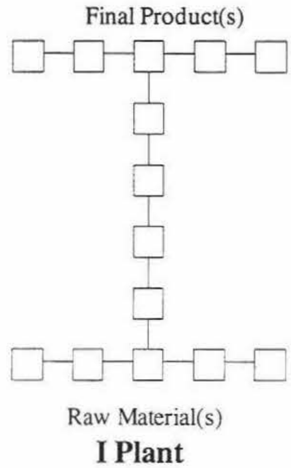


Figure 5.5: Type I Plant Configuration.

An I plant is likely to be a small engineering workshop with small number of finished products, more like a specialised sub-contractor than a complete developer. It is likely to have a single assembly process where dependent events and statistical fluctuations are easily accounted for.

Type Combination-plant

Companies do not always fall neatly into the A-, V-, or T-Plant categories. They may have characteristics of each in various combinations. As an example, a forged products facility may be used to feed an assembly plant. This would be an example of a V-Plant feeding an A-Plant. A customised industrial computer manufacturer may purchase raw components for assembly to stock and then final assembly to order. This would be an example of an A-Plant feeding a T-Plant.

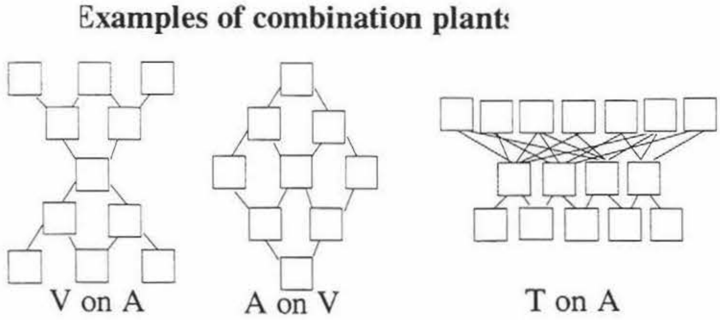


Figure 5.6: Selected Combination Plant Configurations.

Once the product flow diagram is complete it gives a detailed record of the relationship of all part/operations and their associated resources to identify characteristics which are inherent to A-, V- or T-Plants and to understand what instructions are necessary for people who work in specific areas of the production process. As an example, workers in operations just after divergent stations should be aware that a major problem is misallocation and only material required to fulfill the schedule should be taken.

5.7.2 Manufacturing Classification

The second main classification factor to consider in the design of the survey questionnaire is *Manufacturing Category* which refers to nine divisions of manufacturing activities as described in the New Zealand Scientific and Industrial Classification (NZSIC). Prior to sending out the questionnaire there was no intention to influence the number of respondents within any specific manufacturing category (i.e. to prevent bias).

Division 31:	Food, beverage, tobacco
Division 32:	Textile, apparel and leather goods
Division 33:	Wood processing and wood product manufacture
Division 34:	Manufacturing of paper and paper products, printing and publishing
Division 35:	Manufacture of chemicals and of chemical, petroleum, coal, rubber and plastics
Division 36:	Concrete clay, glass, plaster, masonry, asbestos and related mineral product
Division 37:	Basic metal industries
Division 38:	Manufacture of fabricated metal products, machinery and equipment
Division 39:	Other manufacturing industries

Table 5.3: NZSIC Manufacturing Classification.

5.8 Problems Encountered

A problem was encountered during the development of survey instrument when it took sometime for the Massey University Ethics Committee to provide feedback and agreed to the changes made to the survey instruments[36].

Problems were also encountered in ensuring a high response rate. This type of problem was difficult to rectify due to the nature of the survey research where the targeted respondents have the right to decline to respond. Details of the research method and problems experienced during the survey research have been documented in Chapter 6: Survey Results Analysis.

[36] Survey research tool includes the survey questionnaire, introductory letter to accompany the questionnaire and description of research questionnaire.

5.9 Survey Questionnaire: Improvement Opportunities

The researcher acknowledges that the survey questionnaire contained a number of improvement opportunities. The major consideration is in its design where questions and the scale used may each have caused an element of confusion for the respondents and created some difficulties in analysis of some aspects. Examples of flaws contained in the questions are as follows (see also Appendix A: Survey Questionnaire):

Example One:

Question 6 reads:

"If you answered c) in Question 3 please indicate the approximate % of products make to stock and order:"

The question should read:

"If you answered c) in Question 5 please indicate the approximate % of products make to stock and order:"

This is an error that has confused the respondents when answering the question.

Example Two:

The "Rate of Occurrence" scales in Question 12 reads:

☐	Never	☐	Sometimes	☐	Often

The above is thought to limit the scaling scope thus denying a chance for the respondents to choose in a more reflective scale to answer the question. A better measure to use would be a one (lowest) to five (highest) scales, as this gives better numerical choice and might better reflect the occurrence rate of the production related problems.

For this reason a different scale should be used to provide bottom to top scaling with improved proportions. The scale should have read:

☐	Never	☐	Rarely	☐	Sometimes	☐	Often

Another alternative scale that can be used is through both numerical scales and status scales. This is shown as follows:

Never		Sometimes		Often
1	2	3	4	5

The latter scales would provide the respondents with a better chance to reflect the nature of the problems and the numerical data collected would be easier to analyse.

5.10 Chapter Summary

In conclusion, the survey would be useful to help analyse the shopfloor measures application in New Zealand manufacturers. Some of the questions in the survey questionnaire have the objective to confirming theories against actual practices in relation to manufacturing function. The survey has the objectives to identify the type of measures commonly used by different plant types, a series of production tools and policies commonly applied, just to name a few. The data gathered should help describe the nature of manufacturing function of New Zealand manufacturers. The survey questionnaire includes the introduction of the little known type I plant. The existence of type I plant has the potential to open a new area for research as I plant has not been detailed in the list of references used. The survey questionnaire is not entirely flawless and some opportunities for improvements have been identified and discussed.

Chapter Six: Survey Results Analysis

6.0 Introduction

This chapter summarises the survey results analysis for each of the five sections contained in the questionnaire.

6.1 Survey Response

300 survey packs were sent out. 10% positive responses were gathered on the stated due date of Friday 1st May 1998. This prompted a follow up work that saw fifty (50) survey packs sent to selected companies. The follow up survey had a due date on Friday 29th May 1998 and it was followed by telephone calls made to a majority of these companies as a means of tracking survey progress. The follow up work proved beneficial as the response rate increased to 22% or equivalent to 56 positive responses.

Although it is still far from the targeted 30% response rate, the 22% response rate obtained was considered to be the maximum result that can be obtained within the specified time. At that stage it was hoped that the results would be adequate to achieve the research objectives.

Table 6.1 provides a detailed classification of the responses gathered. Note that there are two divisions: "True" and "Original". 'Original' column refers to overall figures for each classification (Respondents, Non-Participants, etc.) from the original target of 300 companies. However, due to some complex issues the original target needed to be adjusted to reflect the problems faced during the survey and was reduced to 258 (see Chapter 6.2: Survey Problems). The updated classifications are shown under the column "True".

	Original		True	
Survey Results	**No.**	**%**	**No.**	**%**
Participants (P)	56	18.67%	56	21.71%
Non-Participants (NP)	16	5.33%	16	6.20%
Not Manufacturing (NM)	18	6.00%	Not Accounted	
Not Suitable (NS)	12	4.00%	Not Accounted	
Returned/Wrong Adress (R/WA)	11	3.67%	Not Accounted	
No Replies (NR)	186	62.00%	186	72.09%
Total (T)	300	100.00%	258	100.00%

Table 6.1: Overall Classification of Survey Responses.

6.2 Survey Problems

There were two major problems encountered during the survey process: low response rate and incorrect company details.

6.2.1 Low Response

It was realised that survey research using a questionnaire form does not guarantee a 100% response rate. Careful steps were taken to ensure maximum response as described in Chapter 5. However, there are the following possible additional causes to the problems associated with the low response rate:

1. The use of a long survey questionnaire form (which consisted of 8 pages) consumed approximately 25 to 30 minutes of productive time.
2. No immediate benefit to the respondent.
3. Confidentiality of specific company data.
4. Lack of company data on performance measures.

In addition to the above points, neither monetary nor material reward was offered for completing the questionnaire as this was considered to have no apparent effect and too costly to be carried out. A brief discussion with a member of the Ethics Committee confirmed that this type of offering was not allowed.

6.2.2 Incorrect Details

The available information needed for sending the survey questionnaire is not free from errors. Due to a large amount of data, it was decided that only a random check would be performed to ensure that the listed companies matched exactly to the criteria. However, this was proved to be insufficient as unforced errors often occurred. Some problems originated from an over-reliance on an off-the-shelf data source[37] and have been classified as the following (also see Figure 6.1 for proportions of these problems):

1. "Non Manufacturing" companies were grouped in the database as manufacturing companies ≈ (NM).
2. The manufacturing component is relatively small in a number of businesses listed in the database as "Manufacturers" therefore they are "Not Suitable" ≈ (NS).
3. Incorrect addresses categorised under "Returned" or "Wrong Address" ≈ (R/WA).
4. A few listed Managing Directors were no longer with the company categorised under "Returned" or "Wrong Address" ≈ (R/WA).
5. Incorrect names, gender labels and functional title.

The above problems have reduced the actual targeted survey population to 256 from the original 300 manufacturing companies targeted (a reduction by approximately 14.7%).

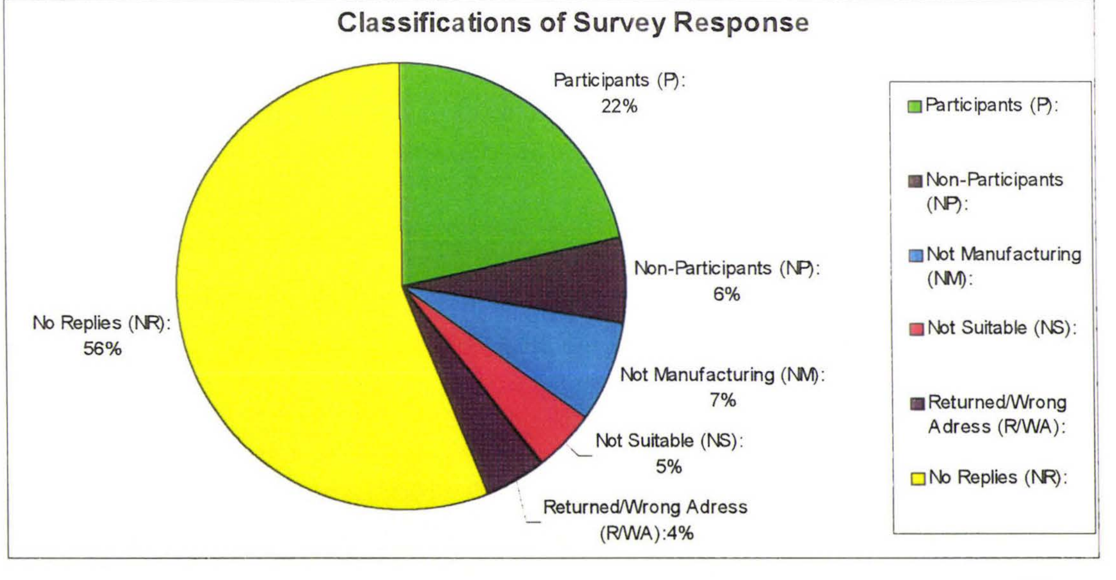


Figure 6.1: Pie-graph Showing "Original" Classification of Survey Response[38].

[37] Kompass CD-ROM Database.
[38] Microsoft Office 97 – Excel Version 7 does not permit both percentage and value to be presented at once, hence separate table and pictorial presentations of survey results.

6.2 Section A: General Enquiries

6.2.1 Objective

The objective was to gather reference information on the respondent that could be useful when further contact needed to be made. The questions aimed at identifying details such as Company Name, Name of Respondent and Contact Details.

6.2.2 Analysis

Reference data was collected if any responses need to be clarified[39].

6.3 Section B: Company Profile

6.3.1 Objective

This section was aimed at gathering profiling information on the respondents' companies such as the number of management levels, number of staff and pre-listed personnel classifications, e.g. Technical, Engineering and Sales.

6.3.2 Analysis

Number of Levels in the Management Hierarchy

The question aimed to identify the relative size of respondents' companies. This was measured in terms of the number of management hierarchy from workers at the shopfloor level to directors in charge of the site.

Range/Count							Count	Aver.	Med.	Max.	Min.	StDev
1	2	3	4	5	6	7						
0	5	12	29	8	0	2	56	3.9	4	7	2	1.0
0.0%	8.9%	21.4%	51.8%	14.3%	0.0%	3.6%	100.0%					

Table 6.2: Overall Response Classification of Management Hierarchy.

Table 6.2 shows the spread of the results obtained in this section. The results show that for the 56 responses the average number of management levels is 3.9 ≈ 4. The table also shows that there are five companies with the least number of management

[39] Softcopies of research data and other survey results are available and is in the custody of the researcher.

levels, at two levels, and two surveyed companies have the highest number of management hierarchy, at seven levels (see columns "1" to "7" in Table 6.2).

There is not enough evidence in the survey data that would suggest a relationship between the number of levels in the management levels and the type of measures and/or the type of concerns that occur. This might be because the type of measures applied is a function of organisational tasks to be analysed (see Chapter 3 for details on the type of measures).

However, it is logical that the total number of measures applied is a function of the number of levels in the management hierarchy. In other words, as the number of levels in the management hierarchy increases the number of measure applied increases.

Company Personnel Classification

Company Personnel Classification	Count	Max.	Min.	Median	Aver.	StDev.	Est.Std. Error of Mean	Skewness
Executive	51	20	1	2	4.3	7.8	1.1	1.7
Sales	46	100	0	9	15.4	20.0	2.9	2.4
Technical	49	220	1	7	19.9	33.0	4.7	4.8
Shopfloor	50	1054	7	66	159.1	218.4	30.9	2.8
Administration	51	170	1	9	20.7	33.1	4.6	3.0
Total company employee	50	1400	5	148	230.7	281.0	39.7	2.6

Table 6.3: Respondents' Company Personnel Classification.

Table 6.3 shows the relative proportion of each personnel classification in the surveyed companies. Both the Median (i.e. 148) and the Average (i.e. 231) figures for the "Total Company Employee" suggest that the target survey group had been reached. The big gap between the Median and the Average figures is due to a small number of companies that employ significantly smaller or larger workforce than the rest of those surveyed, i.e. skewed distribution. This is supported by the figures for total number of employee that ranges from 5 to 1400. One significant out-lier is present in a company that employs only five people (see column "Min." for "Total Company Employee"). However, upon looking at the company type, it can be concluded that this could be caused by the seasonality factor present in many sectors of the manufacturing industry.

Table 6.3 also shows that the Average figures for Sales, Technical and Administration do not differ greatly in size and these three categories made up significantly smaller proportion when compared to the proportion of shopfloor staff for the total number of employees.

At this stage the above descriptions can be considered as adequate to describe the respondents relative size in terms of management hierarchy and workforce. Possibility for further analysis using the data obtained are in such area as to identify the probability of an employment in a particular sector of the company and to identify the approximate number of employees under the management of a average managing director.

6.4 Section C: Production and Operation

6.4.1 Objective

This section had the objective of providing information relating to the company's production operations function. Questions were aimed at identifying the manufacturing category, production type (to order and/or to stock), production flow, scheduling method(s) used and production-related policies used.

6.4.2 Analysis

<u>Manufacturing Category</u>

Table 6.4 shows the classification and the ranking of survey data into nine different divisions as outlined by the NZSIC (see Chapter 5: Survey Research for more details).

3. Manufacturing Category	Survey Results		
	Count	%	Rank
Division 31: food, beverage, tobacco	10	16%	3
Division 32: textile, apparel and leather goods	4	7%	6
Division 33: wood processing and wood product manufacture	5	8%	5
Division 34: manufacturing of paper and paper products, printing and publishing	2	3%	8
Division 35: manufacture of chemicals and of chemical, petroleum, coal, rubber and plastics	9	15%	4
Division 36: concrete clay, glass, plaster, masonry, asbestos and related mineral	1	2%	9
Division 37: basic metal industries	4	7%	6
Division 38: manufacture of fabricated metal products, machinery and equipment	12	20%	2
Division 39: other manufacturing industries	14	23%	1
Total Variant	61	1	

Table 6.4: Survey Results NZSIC Classification.

It can be seen from Table 6.4 that Division 39 at 23% has the highest representation in the survey data, whereas Division 36 at 2% is the lowest. A pictorial presentation of the above proportions is shown in the following Figure 6.2.

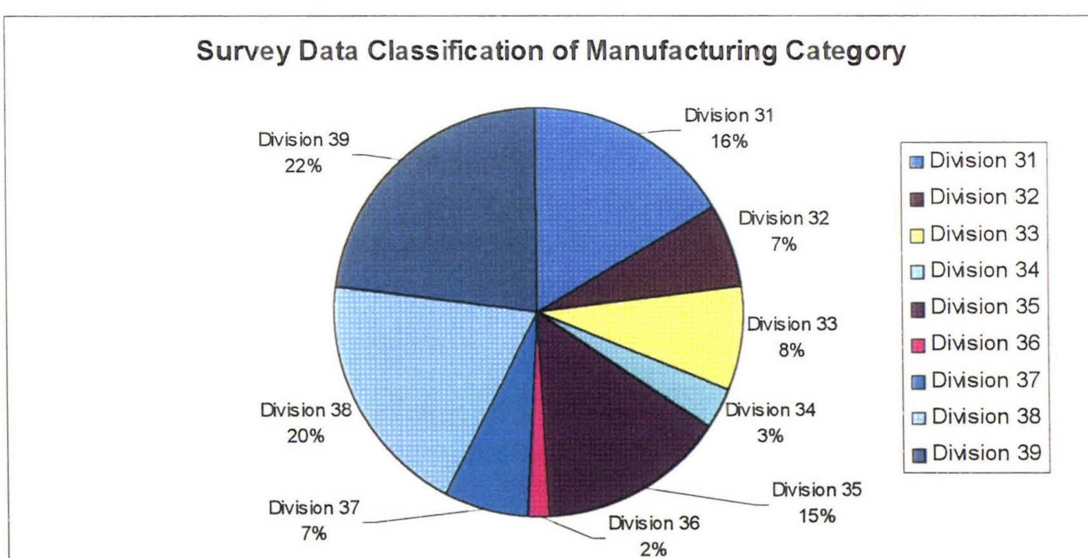


Figure 6.2: Classifications of Manufacturing Divisions in the Survey Data.

3. Manufacturing Category	NZ Statistics							
	0-5	6-9	10-49	50-99	>100	Total	%	Rank
Division 31: food, beverage, tobacco	1372	327	510	105	158	2472	11%	3
Division 32: textile, apparel and leather goods	1559	224	431	63	36	2313	11%	4
Division 33: wood processing and wood product manufacture	2712	396	490	46	30	3674	17%	2
Division 34: manufacturing of paper and paper products, printing and publishing	972	189	373	50	56	1640	8%	5
Division 35: manufacture of chemicals and of chemical, petroleum, coal, rubber and plastics	606	163	350	72	31	1222	6%	6
Division 36: concrete clay, glass, plaster, masonry, asbestos and related mineral product manufacture	670	102	149	9	9	939	4%	8
Division 37: basic metal industries	129	34	56	9	9	237	1%	9
Division 38: manufacture of fabricated metal products, machinery and equipment	5887	966	1233	145	81	8312	38%	1
Division 39: other manufacturing industries	853	84	90	3	1	1031	5%	7
Total Variant	14760	2485	3682	502	411	21840	100%	
			Medium	to	Large			

Table 6.5: New Zealand Statistics Classification of Manufacturing Companies.

Table 6.5 shows the classification of New Zealand manufacturing companies as at September 1998. Columns "10 to 49", "50 to 99" and "100 or more" were added to give an approximate figure for medium to large sized companies (labelled "New Zealand Medium to Large"). This was then used to provide an indication of how the surveyed sample data matches the population as indicated by New Zealand Statistics in Figure 6.3.

As Figure 6.3 shows, the make up of survey respondents do not have close resemblance to New Zealand Statistics' figures. Figure 6.3 shows that there is under-representation and over-representation of New Zealand Statistics figures in the survey data. However, some significant trends shown are: figures of survey data's Division 31, 32, 33, 34, 36 and 38 exceeded that of New Zealand Statistics' figures. This suggests that if questions within the survey provoke answers reflective of industry sector factors then the survey results may not be fully representative of the population mean.

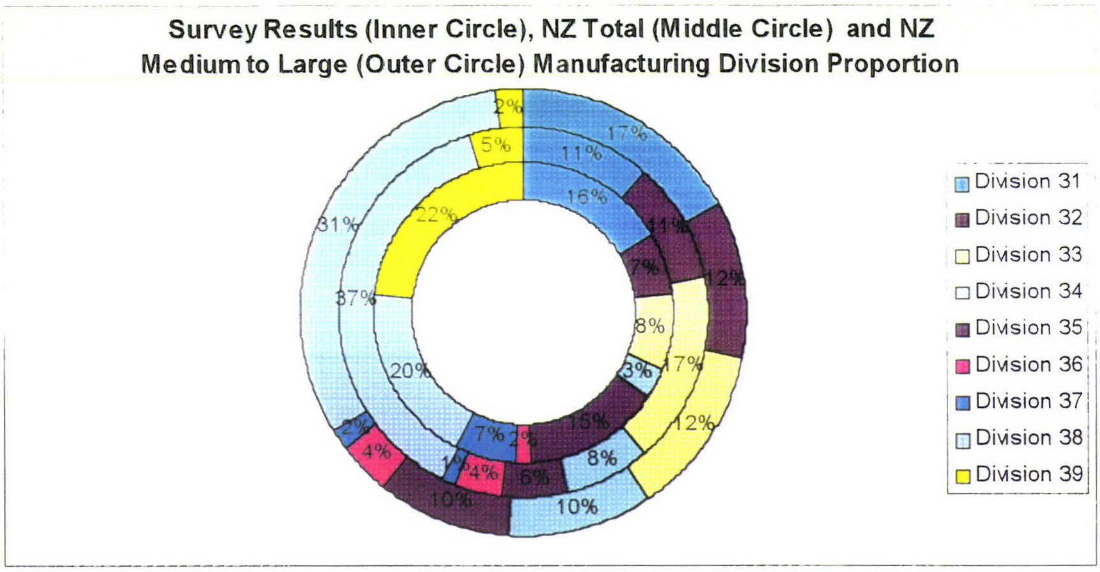


Figure 6.3: Comparison of Manufacturing Division – Survey Response, Total New Zealand Statistics and New Zealand Medium to Large.

Plant Type

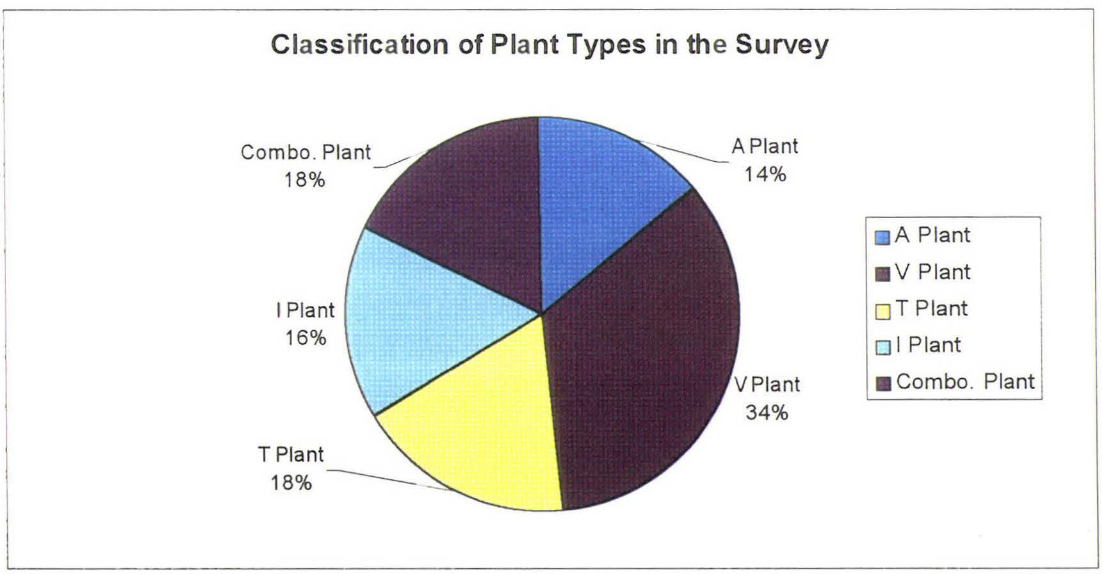


Figure 6.4: Classification of Plant Type in the Survey Data.

Figure 6.4 shows the classification of plant types represented in the survey data. The figure shows that the largest representation is V plant type with 34% and the smallest is A plant with 14%. More detailed account of plant type classification is shown in Table 6.6.

Plant Type	Count	%	Rank
A Plant	8	14%	5
V Plant	19	34%	1
T Plant	10	18%	2
I Plant	9	16%	4
Combination Plant	10	18%	2
Total	56	1	

Table 6.6: Classification of Plant Types in the Survey Data.

In the survey questionnaire a check question was used to confirm the classification of plant types. Question number 4 (see Appendix A: Survey Questionnaire) asked the respondents to indicate the flow of products or the assembly processes, another question utilised a series flow chart for respondents to indicate their plant types (see Q7 in the Appendix A: Survey Questionnaire). However, the results from question number 4 was not conclusive as there was no sub-question that would describe the flow of I Plant, thus data gained from this question was considered to be inadequate for analysis.

Comparison between Manufacturing Division and Plant Type

NZISC	A Plant	V Plant	T Plant	I Plant	Combo.	Total
Division 31	1	4	1	2	2	10
Division 32	0	3	1	0	0	4
Division 33	0	3	1	0	1	5
Division 34	0	2	0	0	0	2
Division 35	1	2	2	3	1	9
Division 36	0	0	0	1	0	1
Division 37	0	3	1	0	0	4
Division 38	4	2	2	1	3	12
Division 39	3	2	3	2	4	14
Total	9	21	11	9	11	61

Table 6.7: Comparison between Manufacturing Division and Plant Types in the Survey.

Table 6.7 shows the classification of both plant types and manufacturing categories represented in the survey data. Note that the "Total" sum of the number of plant types in Table 6.7 (i.e. 61) is different to that shown in Table 6.6 (i.e. 56) due to some companies belonging to two or more plant type and/or manufacturing divisions. For example, there is one type A Plant that belongs to two Manufacturing Divisions.

Both Table 6.6 and 6.8 show that type V plant has the highest representation in the survey data with nineteen plants belonging to twenty-one manufacturing divisions. The majority of each of the plant type in the surveyed companies belongs to equal or similar number of manufacturing divisions.

Table 6.7 shows Manufacturing Division 39 (i.e. "other manufacturing" with 14 varieties across all plant types) has the widest ranging plant types followed by Division 38 (i.e. "fabricated of metal products, machinery and equipment" with 12 varieties across all plant types) and Division 31 (i.e. "food, beverage, tobacco" with 10 varieties across all plant types). In contrast, Division 36 has the least variety of plant types ("concrete clay, glass, plaster, etc." with only 1 I plant) followed by Division 34 ("paper products, printing and publishing" with 2 V plants) and Division 32 ("textile, apparel and leather goods" with 3 V plants and 1 T plant).

No correlation study between manufacturing category and type of measures was taken as it was not included in the objective. However, the data collected shows that New Zealand manufacturers across different manufacturing category were presented in the survey.

Production Types

This section has the objective to classify companies into "Make to Stock", "Make to Order" and/or "Mix of Both Stock and Order". This could be a factor in the management practice as production to order requires different approach to production to stock. The above figures are potrayed in the following Figure 6.4 that shows 72% of the companies in the survey produce to both order and stock, 21% to order and merely 7% are to stock only.

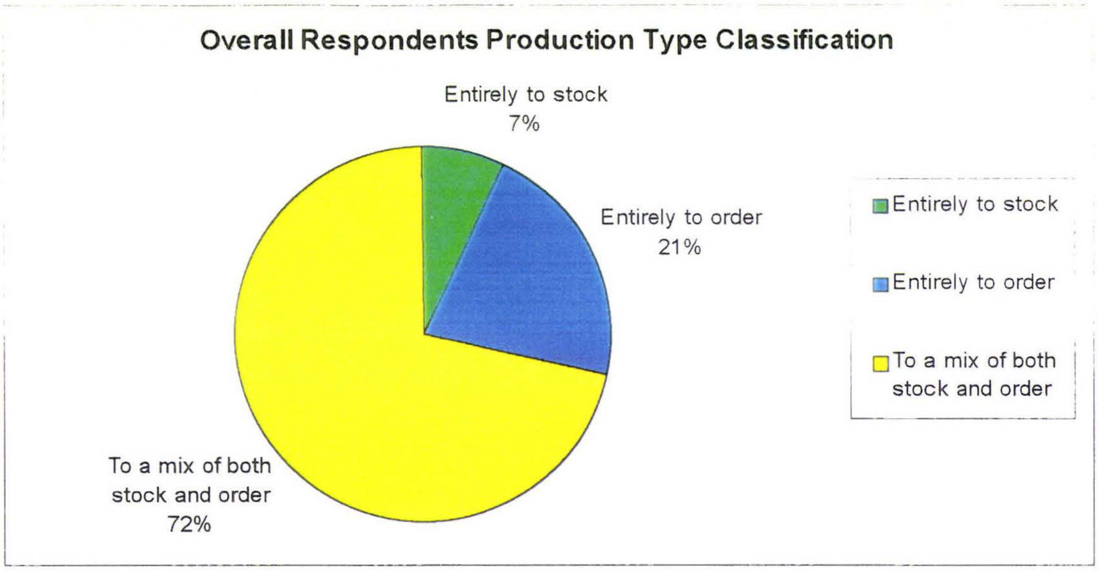
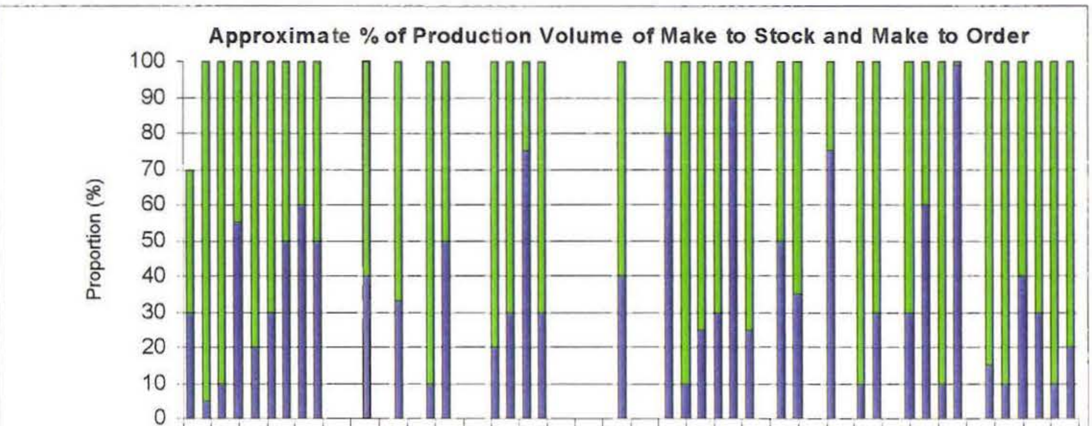


Figure 6.5: Classification of Production Type from Survey data.

This suggest some possibilities as follows:

- A large proportion of the respondents (72%) are producing to both stable (i.e. make to stock) and fluctuating (i.e. make to order) markets. This suggests that management of production operations may be geared to be flexible to accommodate changes in the market. This may suggests that most of the performance measures used will be suited both to "make to order" and "make to stock" production modes.
- Only small proportion of respondents (7%) can rely on a stable market and/or their market fluctuations can be predicted well in advance. It may be possible that these companies are still operating in the 'producer's market' where they have control over the market. This may possibly be due to such things as the 'production of well established consumers products'. Therefore, these companies may be using cost based performance measures as efficiency and low cost accumulating from each work centre performance as the key to ensure profitable operations (see Chapter 2 and 3).
- 21% of respondents are relying on their ability to produce specific products and/or to specific requirements. Therefore, these companies may be putting emphasis on their engineering superiority. 'Conformance to product specifications' and 'Product Quality' related measures might be found in these companies.

The following graphs show the approximate proportion of those companies that make both to stock and order. Table 6.8 shows approximate figures of production volume of make to stock and make to order. Table 6.9 shows approximate figures of the monetary value of the production volume of make to stock and make to order as shown in Table 6.8. Table 6.10 shows the overall classification of make to stock and make to order based on production volume and monetary value. Not all data can be shown due to the graph size and limitations in the software used[40].



Company Number	1	3	5	6	8	10	12	13	15	17	19	20	22	24	26	27	29	31	33	34	36	38	40	41	43	45	47	48	50	52	54	55
Order (Prod. Vol)	40	90	80	70	40		60			50		80	25					20	75	70	75	50		25	90		40	90		90	70	90
Stock (Prod. Vol)	30	10	20	30	60		40			50		20	75					80	25	30	25	50		75	10		60	10		10	30	10

Table 6.8: Approximate % Production Volume of Make to Stock and Make to Order (not all data collected are shown).

The figures in Table 6.8 and the subsequent descriptive analysis in Table 6.10 (row 'A') show the average figures of production to stock (i.e. 36.46%) is lower than the average figures of production to order (i.e. 62.77%). The Median figures, stock at 30% and order at 70%, show figures with close approximation to the Average figures.

[40] Microsoft Excel 7.

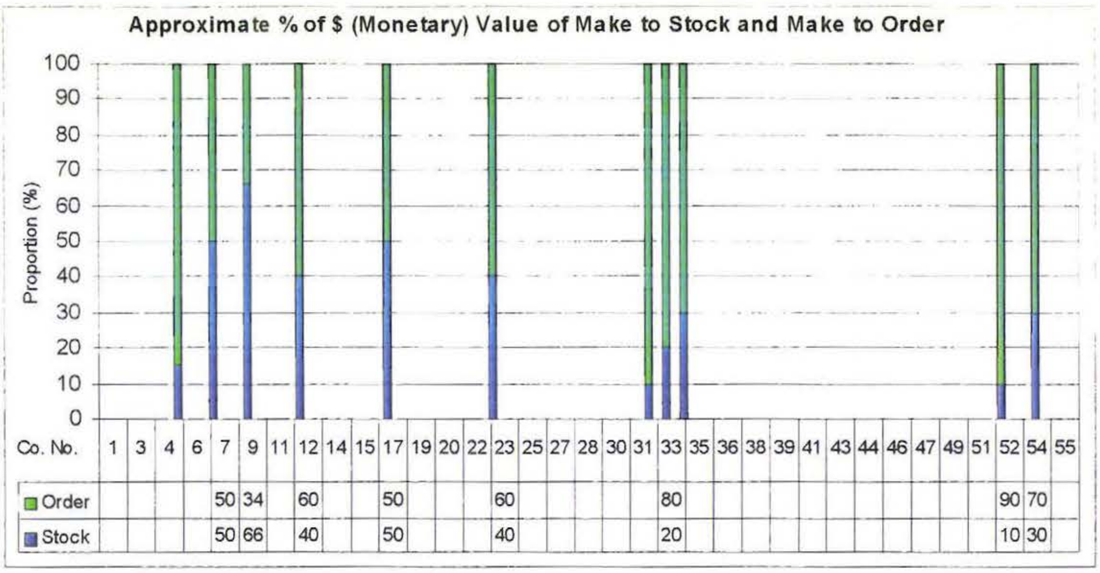


Table 6.9: Approximate % of $ (Monetary) Value of Make to Stock and Make to Order Production (not all data collected are shown).

	Approximate % of products make to stock and order:	Count	Average Prop. (%)	Rank	Max	Min	Median
A	Stock (% Prod. Vol.)	39	36.46	2	99	5	30
	Order (% Prod. Vol.)	39	62.77	1	95	1	70
B	Stock (% $ Value)	9	33.44	2	66	10	30
	Order (% $ Value)	9	66.56	1	90	34	70

Table 6.10: Overall Classification of Make to Stock and Make to Order based on Production Volume and Monetary Value.

The figures in Table 6.9 and the subsequent descriptive analysis in Table 6.10 (row 'B') show the average figure of production to stock (i.e. 33.44%) is lower than the average figure of production to order (i.e. 65.56%). The Median figure, stock at 30% and order at 70%, show figures with close approximation to the Average figures and also is similar to the figures for the production volume as described previously.

These results show that make to order is more significant in terms of production volume and has more monetary value to the respondents' companies who engaged in both make to stock and make to order.

Scheduling Method

Figure 6.5 and Table 6.11 show the classification of Scheduling Methods in popular use as found in the surveyed companies. The respondents were asked to choose from a prearranged list of well-known scheduling methods. In addition, the respondents were able to include any other scheduling mechanism employed. The type of scheduling employed has significant effect on how manufacturing operations are controlled and measured.

An illustration to some of the differences between three scheduling tools are as follows (Aggarwal, 1985):

1. Materials Requirements Planning (MRP) allows for an extraordinary degree of advance planning for medium level inventory, mass production companies but at a cost in inflexibility and informality.
2. Just-in-Time (JIT) or "Kanban" keeps inventory costs down and involves employees but requires well structured supply lines and cooperative workers.
3. Optimised Production Technology (OPT)/Drum-Buffer-Rope (DBR) focuses on clearing up bottlenecks in the manufacturing process but can adversely affect non-bottleneck areas and is a proprietary system.

Figure 6.5 shows that 'Spreadsheet' at 22% is the most popular scheduling tool among respondents followed by 'Others' (custom built scheduling mechanisms) at 13%, MRP and JIT both at 11% and MRP II at 10%. The least popular scheduling technique is DBR/OPT at 2%. This shows that two surveyed companies have adapted the TOC plant control philosophy and it shows a potential for growth for TOC principles and its application.

Scheduling Method	Count	%	Rank
MRP	11	11%	3
MRP II	10	10%	5
DBR/OPT	2	2%	11
Critical Path	9	9%	6
JIT	11	11%	3
Kanban Card	9	9%	6
First-Come-First-Serve	6	6%	8
Gantt Chart	4	4%	9
Spreadsheet	22	22%	1
None	3	3%	10
Others (Specified)	13	13%	2
Total	100	1	

Table 6.11: Overall Respondents Production Scheduling Method Classification.

Table 6.11 show that there are 100 scheduling methods used by 56 respondents, which mean that there are two or more combination of scheduling techniques employed in some companies. This is possible with some technique applicable only for a particular production phase and, therefore, another scheduling mechanism would be required to complete the scheduling function.

It also shows that three companies were not shown to have some form of scheduling mechanism in place (see Table 6.11 row 'None'). There are a few possible reasons to this phenomenon:

- The manufacturing activities do not vary greatly. Hence, a simple scheduling is all that needed to determine processes to good accuracy.
- Confidentiality of company data might have prevented the respondent(s) from completing this particular question.

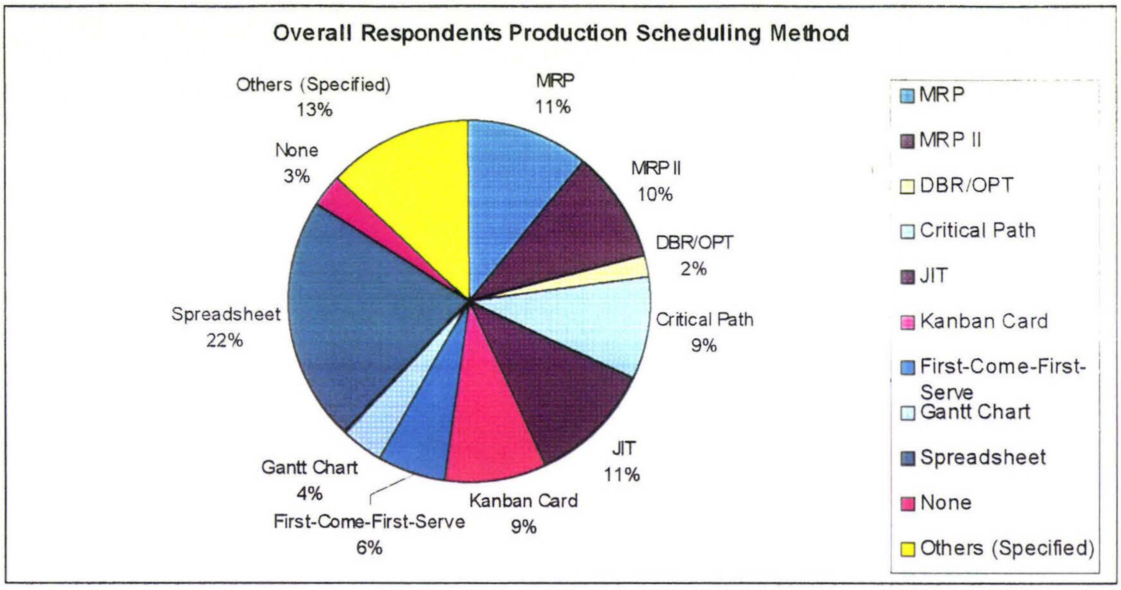


Figure 6.5: Classification of Scheduling Method in Popular Use by the Survey Respondents.

The analysis for this section was considered to be adequate for the purpose of this study, as there is enough information that describes some of the production operations aspects of the respondents' companies. No further analysis was carried out using the data gained in this section. However, there are the following possibilities for analysis subject to applicability:

- To analyse the appropriateness of a particular scheduling method for capacity planning and control and for their role in defining shopfloor measures.
- To analyse the type of measures employed for each plant using a particular scheduling method and other additional combinations.

Production Batch Splitting and Minimising Setups Policies

The respondent was asked whether there are "Production Batch Splitting" and "Minimising Setups" policies in place. This was intended to assist in the identifying the existence of some traditional measures such as localised efficiency measures.

Figure 6.6 shows 58% of the surveyed companies have the Batch Splitting policy compared to 13% indicating no such policy existed in their companies and 29% of the surveyed companies indicated such policy is Not Applicable (N/A) in their companies.

A possible interpretation from this is that 58% of the surveyed companies saw the need to split production batches to accommodate the need to increase production variety and reduce lead-time as advocated by Just-in-Time policies and Theory of Constraints production application (Goldratt and Fox, 1986). Those companies, which do not have such policy, may not see the need to split batches, as there is not enough pressure for it to be exercised.

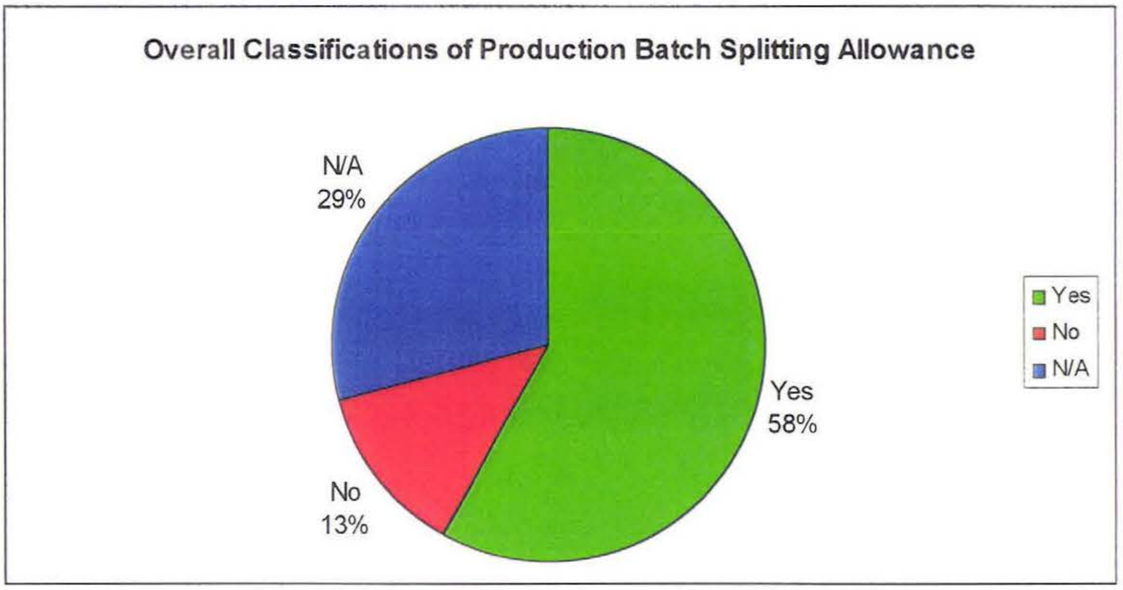


Figure 6.6: Classification of Production Batch Splitting Policy.

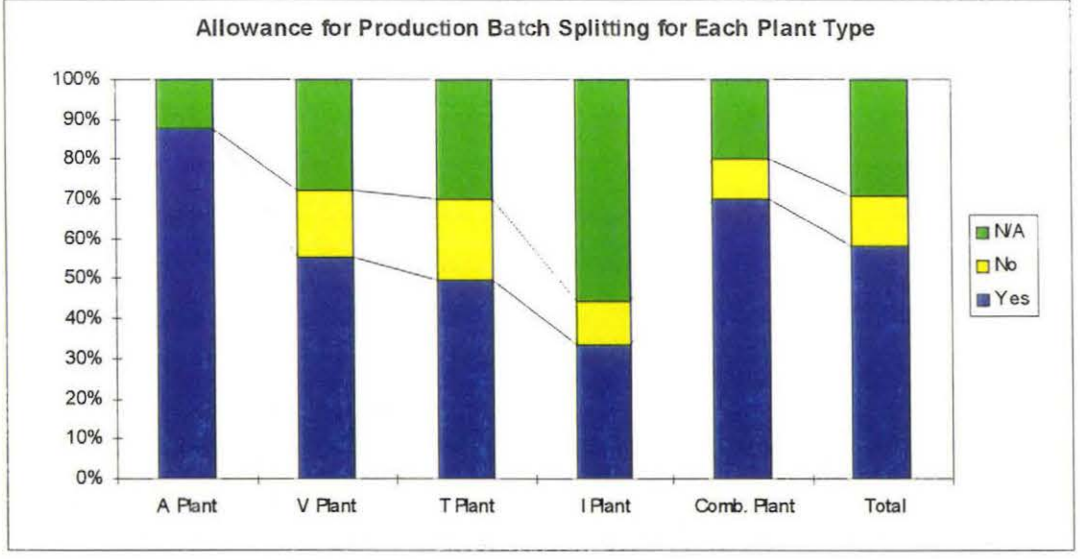


Figure 6.7: Distribution of Production Batch Splitting Allowance for Each Plant Types.

Figure 6.8 shows the proportion of companies employing a 'Minimising Setups' policy. Using traditional cost based principles, this policy deals with ensuring high efficiency by minimising downtime due to setup. The classification shows that 70% of those surveyed indicated the existence of such a policy and 12% indicated they had no such policy, while 18% indicated that this policy does not apply, to their circumstances.

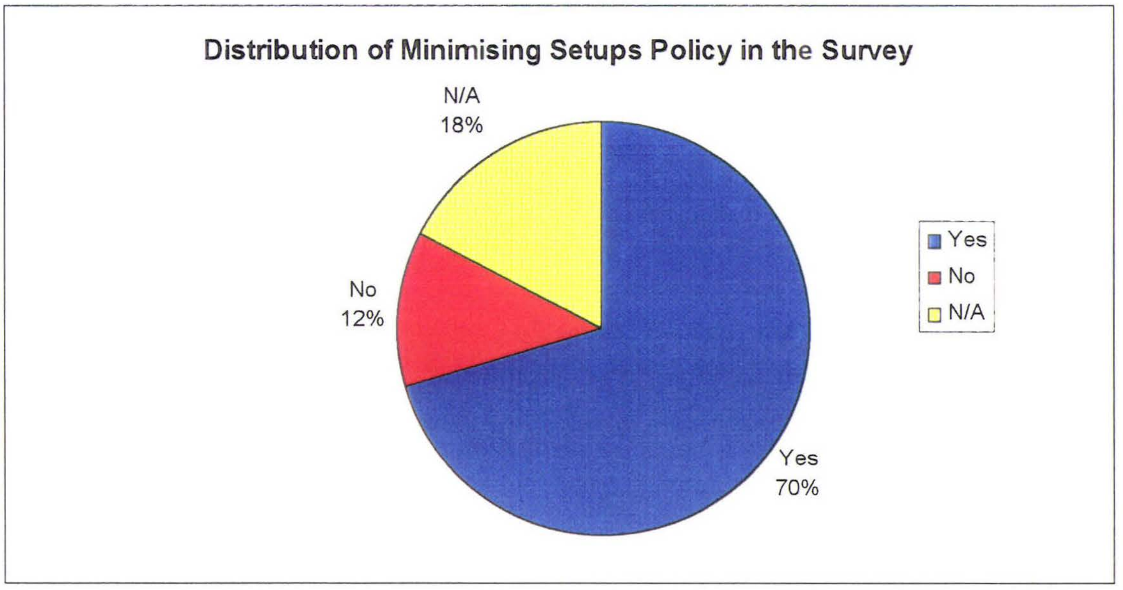
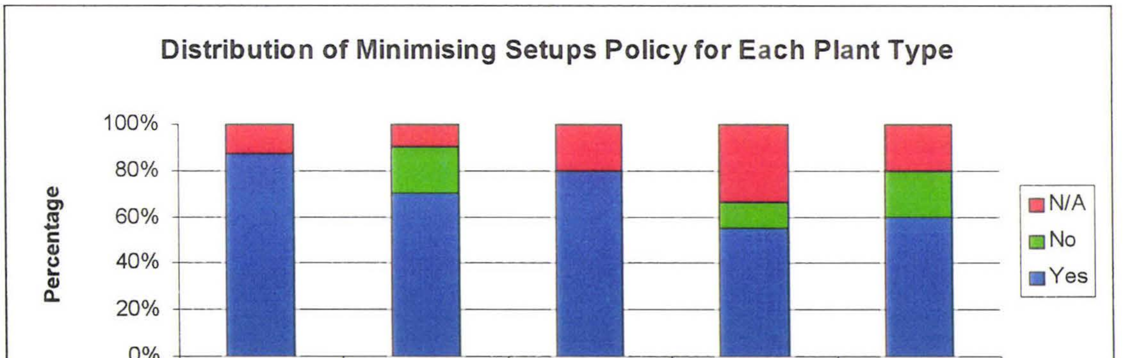


Figure 6.8: Distribution of Minimising Setups Policy in the Survey.



	A Plant	V Plant	T Plant	I Plant	Combo Plant
N/A	1	2	2	3	2
No	0	4	0	1	2
Yes	7	14	8	5	6

Figure 6.9: Distribution of Minimising Setups Policy for Each Plant Type.

6.5 Section D: Shopfloor Performance Measures

6.5.1 Objective

The objective of this section is to identify the type of measures in popular use and common production related problems. It is important to identify not only the measures in current use but also the perceived level of importance and usefulness of the measures. By the same token, problems experienced will be measured for their occurrence rate and impact to companies' financial status.

Other additional questions in this section were aimed at identifying the perceived success rate of current shopfloor performance measurement systems and the reasons for selecting the score. In addition, the respondents were asked for their opinions on possible improvement avenues using a free form response (i.e. respondents were allowed to express their own opinion freely).

6.5.2 Analysis

Shopfloor Performance Measures

This section aimed to gather a list of performance measures in popular use as well as their level of importance and usefulness rating. Respondents were asked to rank a list of prearranged measures for their level of importance and usefulness rating using a scale of 1 (lowest) to 5 (highest). In addition, respondents were asked to list additional measures used at their companies and rank these measures using the same method as described previously.

There are the following key analyses carried out:

1. To quantify shopfloor performance measures' level of importance.
2. To quantify shopfloor performance measures' usefulness rating.
3. To identify whether the perceived level of importance equals to the usefulness rating.

Shopfloor Performance Measures: Level of Importance

Rank	Measures	Average	Count	Throughput/ Cost World
1	Others (company specific)	5.00	7	
2	Conformance to specifications	4.72	50	T
3	On-time delivery	4.63	48	T
4	Budget/Operating variances	4.17	47	C
5	Direct labour productivity	4.11	45	C
6	Dollars shipped per period	3.97	30	T
7	Cost reduction/ dollar savings	3.95	42	C
8	Response time	3.91	34	T
9	Conformance to production schedule	3.87	46	T
10	Machine efficiency	3.81	37	C

Table 6.12: Top 10 Measures Based on Level of Importance Average Score – Overall Respondents.

Table 6.12 shows top 10 measures based on level of importance average score for overall respondents. It consisted of five columns: 'Rank' for the measures ranking, 'Average' displays the average scores, 'Count' displays the number of response received for that particular measure and 'Throughput/ Cost World' displays whether the measures is of 'Throughput World' (classified as 'T') or 'Cost World' (classified as 'C') measure type.

Table 6.12 shows that the highest ranked measure is 'Others'[41] which relates to measures developed to meet specific company requirements. The following are the names of some those specific measures as detailed by the respondents:

- Safety Performance.
- IFOTIS.
- Throughput (Kg/Hr = $/Hr).
- Field MTBF, Executable Due Date Performance, Customers Complaints, Time to execute Customer Complaints.
- Dollars Shipped / Tonne.
- Recovery Rate.
- $Total Factory Cost/Kg. Whsed, $Conversion/Kg. Whsed.

No additional information about the application of these measures were given by any of the respondents.

Note that measures ranked 4,5, 7 and 10 can be considered as 'efficiency' measures with focus on cost. Measures ranked 2,3,6,8 and 9 can be considered as Throughput World measures and thus, they are classified as 'T'. 'Others' was not classified into either T or C as they were created for specific purposes and were difficult to classify.

Table 6.13 shows top 10 measures based on level of importance average scores for each plant type (i.e. A, V, T, I and Combination). There is a range of measures in each of the top 10 but there remains a varying degree of combination of throughput and cost measures. The top 10 measures for A Plant do not include 'Others' unlike the other plant types where it is ranked first. This comes from the fact that no type A Plant in the surveyed companies used company specific measure. Some notable classifications are 'Conformance to Specifications' which ranked in the top 3 average scores for each plant type and 'On-time Delivery' which appears in the top 4 average scores for each plant type.

The mixed results of cost and throughput world measures in the ranking of measures' level of importance might suggest the existence of some kind of conflict between the

[41] There is inadequate information to display the names of these specific measures.

adoption of Cost World principles and Throughput World principles in the surveyed companies.

See Appendix E: Survey Results for more details.

Plant	A			V			T			I			Combination		
Rank	**Measures**	**Aver**	**T/C**	**Measures**	**Aver**	**T/C**	**Measures**	**Aver**	**T/C**	**Measures**	**Aver**	**T/C**	**Measures**	**Aver**	**T/C**
1	Conformance to specifications	5.00	T	Others (company specific)	5.00		Others (company specific)	5.00		Others (company specific)	5.00		Others (company specific)	5.00	
2	On-time delivery	4.63	T	Conformance to specifications	4.67	T	On-time delivery	4.60	T	Conformance to specifications	4.71	T	Conformance to specifications	4.75	T
3	Cost per part	4.40	C	On-time delivery	4.61	T	Conformance to specifications	4.56	T	Machine activation	4.67	C	On-time delivery	4.71	T
4	Direct labour productivity	4.14	C	Response time	4.42	T	Direct labour productivity	4.38	C	On-time delivery	4.60	T	Dollars shipped per period	4.33	T
5	Conformance to production schedule	4.00	T	Budget/Operating variances	4.41	C	Conformance to production schedule	4.25	T	Machine efficiency	4.50	C	Labour efficiency	4.29	C
6	Standard hours produced	4.00	C	Direct labour productivity	4.38	C	Standard hours produced	4.00	C	Budget/Operating variances	4.50	C	Direct labour productivity	4.25	C
7	Cost of quality	4.00	C/T	Machine efficiency	4.27	C	Cost per part	4.00	C	Process setup costs	4.00	C	Budget/Operating variances	4.13	C
8	Overhead cost	4.00	C	Cost reduction/ dollar savings	4.13	C	Dollars shipped per period	4.00	T	Cost reduction/ dollar savings	4.00	C	Labour utilisation	3.86	C
9	Cost reduction/ dollar savings	4.00	C	Production lead times	4.07	C/T	Cost reduction/ dollar savings	3.86	C	Downtime	4.00	C/T	Inventory turnover	3.83	C/T
10	Labour utilisation	4.00	C	Scrap cost	4.07	C/T	Budget/Operating variances	3.75	C	Response time	3.67	C/T	Response time	3.83	C/T

Table 6.13: Top 10 Measures' Level of Importance for Each Plant Type.

Usefulness Rating

Rank	Measures	Average	Count	Throughput/ CostWorld
1	Others (company specific)	4.86	7	
2	Conformance to specifications	4.57	49	C/T
3	On-time delivery	4.53	47	T
4	Budget/Operating variances	4.13	46	C
5	Direct labour productivity	3.93	44	C
6	Cost reduction/ dollar savings	3.93	41	C
7	Machine efficiency	3.89	37	C
8	Conformance to production schedule	3.88	40	T
9	Production lead times	3.87	38	T
10	Downtime	3.83	41	C/T

Table 6.14: Usefulness Rating using Average Score – Overall Respondents.

The measures shown in Table 6.14 have been ranked using usefulness score assigned by the respondents. The ranking shows the same top five measures as found in Table 6.12, and both tables also show the measures have similar scores. It is interesting to note the distribution of Cost World measures in this ranking, as they appear to be more dominant than Throughput World measures. This could mean that the respondents did not view Throughput measures as more useful than Cost World measures. Hence, this tells a little bit about the respondents' view on Cost World principles and the focus on localised improvement. However, the first three measures in this ranking are Throughput World measures and suggest that even though they might not be as popular as other types of measure, their usefulness have significant place in respondents' view. This also suggests that there is a tug of war between Cost World and Throughput World principles. On one hand, Throughput measures were seen as the more appropriate measures to use, but on the other hand Cost World measures took precedence as they helped improve short-term performance.

Table 6.15 shows the classifications of measures' usefulness rating for each plant type surveyed. The table shows, once again, the combination of Throughput World and Cost World that measures that suggests a tug of war as explained above.

Plant	A			V			T			I			Combination		
Rank	Measures	Aver	T/C	Measures	Aver	T/C	Measures	Aver	T/C	Measures	Aver	T/C	Measures	Aver	T/C
1	Conformance to specifications	4.88	T	Others (company specific)	5.00		Conformance to specifications	4.78		Others (company specific)	5.00		Others (company specific)	5.00	
2	On-time delivery	4.38	T	On-time delivery	4.56	T	On-time delivery	4.40	T	On-time delivery	4.75	T	On-time delivery	4.71	T
3	Overhead cost	4.25	C	Conformance to specifications	4.44	T	Standard hours produced	4.29	C	Budget/Operating variances	4.29	C	Conformance to specifications	4.63	T
4	Conformance to production schedule	4.20	T	Budget/Operating variances	4.41	C	Direct labour productivty	4.25	C	Cost reduction/ dollar savings	4.25	C	Dollars shipped per period	4.00	T
5	Standard hours produced	4.17	C	Production lead times	4.27	T	Budget/Operating variances	4.25	C	Conformance to specifications	4.17	T	Cost reduction/ dollar savings	3.88	C
6	Cost reduction/ dollar savings	4.17	C	Response time	4.25	T	Cost of quality	4.14	C/T	Production lead times	4.00	T	Direct labour productivity	3.88	C
7	Production lead times	4.00	T	Direct labour productivity	4.06	C	Conformance to production schedule	4.00	T	Scrap cost	4.00	C/T	Budget/Operating variances	3.88	C
8	Dollars shipped per period	4.00	T	Machine efficiency	4.06	C	Others (company specific)	4.00		Cost of quality	4.00	C/T	Conformance to production schedule	3.83	T
9	Downtime	4.00	C/T	Scrap cost	4.00	C/T	Overhead cost	3.88	C	Machine efficiency	4.00	C	Overhead cost	3.75	C
10	Direct labour productivity	3.86	C	Downtime	3.95	C/T	Inventory turnover	3.75	C/T	Downtime	4.00	C/T	Machine efficiency	3.67	C

Table 6.15: Top 10 Measures' Usefulness Rating for Each Plant Type.

Shopfloor Performance Measures: Pearson Correlation

The analysis carried out used Pearson Correlation Values to measure the correlation between the measures' level of importance and usefulness rating. The Pearson Values described in Table 6.16 were used in the hypothesis tests for this section of the survey.

Pearson Value	Count	Description
0 to +/- 0.25	0	Little or No Relationship
+/- 0.26 to +/- 0.50	0	Fair Degree of Relationship
+/- 0.51 to +/- 0.75	0	Moderate to Good Relationship
Over +/- 0.75	0	Very Good to Excellent Relationship

Table 6.16: Pearson Correlation Values.

The hypotheses are as follows:

Hypothesis	Definitions
A. Null Hypothesis, H_0	If the measure's Pearson Value was found to be in the range of +/-0.51 to +/- Over 0.75 (i.e. 1) then there is moderate to excellent relationship between measures' level of importance and usefulness rating.
B. Alternative Hypothesis, H_1	If the measure's Pearson Value was found to be in the range of 0 to +/-0.50 then there is little to fair degree of relationship between measures' level of importance and usefulness rating.

Table 6.17: Pearson Correlation Hypotheses Definitions.

Table 6.18 shows the spread of Pearson values in the survey data. The values range from 0.55 (i.e. the lowest) to 0.89 (i.e. the highest). This suggests that measures' level of importance have moderate to excellent relationship to measures' usefulness rating.

Item	Pearson
Highest	0.89
Median	0.75
Average	0.74
Lowest	0.55

Table 6.18: The Spread of Results Data for the Pearson Correlation between Measures' Level of Importance and Usefulness Rating.

Table 6.19 shows top 10 Pearson values for measures, the complete list is shown in the Appendix E - Table E7. The Pearson values shown indicate that the respondents have good confidence that the assigned level of importance to the measures used is in accordance to respondents' view on measures' usefulness in achieving the company's goal.

Rank	Performance Measure	Pearson
1	Machine activation	0.89
2	Process setup costs	0.89
3	Conformance to production schedule	0.85
4	Standard hours produced	0.85
5	Rework cost	0.85
6	Downtime	0.84
7	Quality costs per unit of labour	0.84
8	Process setup times	0.80
9	Production lead times	0.80
10	Cost of quality	0.79

Table 6.19: Pearson Correlation between Measures' Level of Importance and Usefulness Rating.

Company Concerns

This section has the objective to gather a list of popular company concerns as well as their rate of occurrence and their financial impact. Respondents were asked to indicate the type of concerns, their rate of occurrence and their financial impact. Two scales consisting of three levels each were used in the process. One uses "Never" – "Sometimes" – "Often", another uses "Small" – "Medium" – "Large" scales[42]. For analysis purposes, "Never" and "Small" were given a numerical value "1", "Sometimes" and "Medium" were given a numerical value "2", and "Often" and "Large" were given numerical value "3". The numerical values made a series of statistical analysis possible.

Descriptive analyses were carried out using the data obtained in this section. The following key analyses were carried out:

1. To calculate the rate of occurrence of specific company concern.
2. To calculate the financial impact of specific company concern.
3. To identify the correlation between the concerns' occurrence rate to the financial impact using Pearson Correlation.

[42] See Chapter 5 under "Survey Instruments' Opportunity for Improvement" regarding the use of these scales.

Company Concerns: Rate of Occurrence

Table 6.20 shows the overall ranking of company concern based on the average score assigned to their rate of occurrence. The 10 scores range from the lowest of 1.93 to the highest of 3. This means the top 10 concerns occurrence rate range from sometimes to often.

Note that the score given by the respondents to 'Others' or company specific concerns are usually large (i.e. they occur often at that company). The only details of the specific or 'Others' problems as submitted by the respondents are as follows:

- Contracts mismanaged by sales.
- Rework due to design issues.
- Setup Scrap (too high), Products Variants (too high).

The respondents whose specific or 'Other' measures were highly rated made no additional information available.

Rank	Concerns	Average	Count
1	Others (company specific)	3.00	1
2	Forecasts are often not correct	2.42	55
3	The plant experiences wave-like flow of work	2.04	53
4	Products do not get sold immediately	2.02	54
5	We have high documentation of activities	1.98	54
6	Too much raw materials inventory	1.94	54
7	We have too many setups	1.94	51
8	We have trouble meeting production due dates	1.93	56
9	Unplanned overtime	1.93	55
10	Inventory carrying costs are too high	1.93	54

Table 6.20: Top 10 Company Concerns Ranked Using Rate of Occurrence Scores – Overall Plants.

Table 6.21 shows top 10 concerns' rate of occurrence for each plant type in the survey. Complete list of company concerns and their occurrence rating are shown Appendix E.

Plant	A		V		T		I		Combination	
Rank	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver
1	Forecasts are often not correct	2.25	Others (company specific)	3.00	Forecasts are often not correct	2.40	Forecasts are often not correct	2.44	Forecasts are often not correct	2.56
2	Inventory carrying costs are too high	2.00	Forecasts are often not correct	2.42	Unplanned overtime	2.33	There is lack of staff able to perform cross functional tasks	2.22	We have long production lead times	2.20
3	Products do not get sold immediately	1.88	Products do not get sold immediately	2.37	We have high documentation of activities	2.25	We have high documentation of activities	2.11	The sales department expect unrealistic delivery times	2.20
4	We have shortages of some sub-component at assembly points in the plant	1.88	The plant experiences wave-like flow of work	2.22	We have trouble meeting production due dates	2.20	Inter-departmental conflict is common	2.11	There is a lot expediting	2.13
5	We have trouble meeting customer orders on time	1.88	We have high documentation of activities	2.11	We have shortages of some sub-component at assembly points in the plant	2.11	The plant experiences wave-like flow of work	2.00	We have too many setups	2.13
6	We have long production lead times	1.88	Too much finished goods inventory	2.05	Labour efficiencies/ utilisation are too low	2.11	Process change over (setups) takes too long	2.00	Too much raw materials inventory	2.11
7	The plant experiences wave-like flow of work	1.88	Inventory carrying costs are too high	2.05	The plant experiences wave-like flow of work	2.11	Too much raw materials inventory	1.89	Products do not get sold immediately	2.10
8	Process change over (setups) takes too long	1.88	We have trouble meeting production due dates	2.00	Too much raw materials inventory	2.10	There are walls of distrust between staff at various management levels	1.89	Too much finished goods inventory	2.00
9	The sales department expect unrealistic delivery times	1.86	We have trouble meeting customer orders on time	2.00	We have considerable amount of scrap/ high re-work	2.00	Sales accuse production of being too slow to respond	1.89	Unplanned overtime	2.00
10	Too much raw materials inventory	1.75	There is a lot expediting	2.00	There is lack of staff able to perform cross functional tasks	2.00	There is a "protect your rear parts" mentality among staff members	1.89	Resource utilisations are perceived to be unsatisfactory	2.00

Table 6.21: Top 10 Company Concerns Ranked Using Rate of Occurrence Scores – All Plants.

Company Concerns: Financial Impact

Table 6.22 shows the top 10 ranking of company concerns using the scores given by the respondents on the financial impact of the problems to the respondents' company. The top 10 scores range from the lowest of 1.77 to the highest of 3.00. This means the financial impact of top 10 concerns range from small-medium to large.

Note that 'Others' was again ranked first meaning these company specific concerns resulted in large financial impact.

Rank	Concerns	Average	Count
1	Others (company specific)	3.00	1
2	Too much raw materials inventory	2.00	51
2	Too much finished goods inventory	2.00	51
4	Forecasts are often not correct	1.98	50
5	Inventory carrying costs are too high	1.90	50
6	We have trouble meeting customer orders on time	1.87	53
7	Labour efficiencies/ utilisation are too low	1.86	49
8	Products do not get sold immediately	1.78	49
9	We have trouble meeting production due dates	1.77	53
10	We have too many setups	1.77	43

Table 6.22: Top 10 Company Concerns Ranked by Financial Impact Scores – Overall Response.

Table 6.23 shows top 10 concerns' financial impact for each plant type in the survey. Complete list of company concerns and their financial impact scores are shown Appendix E.

Plant	A		V		T		I		Combination	
Rank	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver
1	Forecasts are often not correct	2.14	Others (company specific)	3.00	Resource utilisations are perceived to be unsatisfactory	2.29	Labour efficiencies/ utilisation are too low	2.33	Forecasts are often not correct	2.38
2	We have trouble meeting production due dates	1.88	Too much finished goods inventory	2.21	We have trouble meeting customer orders on time	2.22	We have considerable amount of scrap/ high re-work	2.17	Too much finished goods inventory	2.10
3	We have trouble meeting customer orders on time	1.88	Too much raw materials inventory	2.17	There are walls of distrust between staff at various management levels	2.17	Forecasts are often not correct	2.14	We have trouble meeting production due dates	2.00
4	Produce much more than market demands	1.86	Inventory carrying costs are too high	2.16	Too much raw materials inventory	2.11	Too much raw materials inventory	2.00	We have trouble meeting customer orders on time	1.90
5	Too much finished goods inventory	1.75	Labour efficiencies/ utilisation are too low	2.00	Inventory carrying costs are too high	2.00	Inventory carrying costs are too high	1.83	Too much raw materials inventory	1.89
6	Inventory carrying costs are too high	1.75	Products do not get sold immediately	1.95	We have high documentation of activities	2.00	Resource utilisations are perceived to be unsatisfactory	1.83	Products do not get sold immediately	1.78
7	The plant experiences wave-like flow of work	1.75	We have too many setups	1.88	Labour efficiencies/ utilisation are too low	2.00	We have too many setups	1.83	The sales department expect unrealistic delivery times	1.75
8	Our estimated sales inflate demands on production	1.67	Forecasts are often not correct	1.84	The plant experiences wave-like flow of work	2.00	Process change over (setups) takes too long	1.83	We have shortages of some sub-component at assembly points in the plant	1.70
9	Too much raw materials inventory	1.63	We have considerable amount of scrap/ high re-work	1.83	Process change over (setups) takes too long	2.00	The plant experiences wave-like flow of work	1.75	We have long production lead times	1.70
10	We have shortages of some sub-component at assembly points in the plant	1.63	We have trouble meeting customer orders on time	1.79	We have trouble meeting production due dates	1.89	There are walls of distrust between staff at various management levels	1.75	Parts common to several products end up in the products not currently in demand	1.67

Table 6.23: Top 10 Company Concerns Ranked by Financial Impact – All Plants.

Company Concerns: Pearson Correlation

Rank	Company Concerns	Pearson
1	There is a lot expediting	0.69
2	We have too many setups	0.64
3	Process change over (setups) takes too long	0.61
4	Products do not get sold immediately	0.60
5	The plant experiences wave-like flow of work	0.60
6	Resource utilisations are perceived to be unsatisfactory	0.54
7	Production batch sizes are too large	0.51
8	We have considerable amount of scrap/ high re-work	0.51
9	We have to split batches to rush product through for a customer order	0.51
10	There is lack of staff able to perform cross functional tasks	0.50

Table 6.24: Top 10 Pearson Correlation Values between Concerns' Rate of Occurrence and Financial Impact.

Item	Pearson
Highest	0.69
Median	0.40
Average	0.40
Lowest	0.04

Table 6.25: The Spread of Pearson Correlation Values between Concerns' Rate of Occurrence and Financial Impact.

Table 6.25 shows a wide range of Pearson Values between concerns' occurrence rate and financial impact. The lowest is 0.04 (Little or No Relationship) whereas the highest is 0.69 (Moderate to Good Relationship), while the Average figure shows 0.40 or a Fair Degree of Relationship. This suggests that it is possible for the company concerns or production related problems to occur on regular basis and yet no significant financial impact is incurred.

See Appendix E: Survey Results for more details.

Success Rate of Current Shopfloor Performance Measurement System

This section is aimed at identifying respondents' perceived success rate of their current shopfloor performance measurement system. The scale used range from 1 (i.e. lowest) to 5 (i.e. highest). In addition, the respondents were asked for their opinions of possible improvement to the current system. A major outcome from this question was the gathering of free form responses based on respondents' knowledge and valuable experiences of using a particular system.

Table 6.17 indicates the classification of the respondents' perceived success rate of the performance measurement system currently being implemented in their companies. The table shows that 10% of the respondents scored 1 to 2 which indicates possibility for significant improvements and 90% of the respondents scored 3 to 5 which indicates possibility for medium to small-scale improvements opportunities. Detailed breakdown of the classifications can be seen in Table 6.17 and Figure 6.8.

The above results show that majority of respondents saw minor to medium scale improvement opportunities from current performance level. However, possibility of some bias were felt as the question asked for respondents' perceived rate of success and being human they are likely to rate themselves on average or better.

Scale	Count	%	Rank
1 = Lowest	0	0.00%	5
2	5	10.00%	3
3	17	34.00%	2
4	24	48.00%	1
5 = Highest	4	8.00%	4
Total	50	100%	

Table 6.26: Perceived Success Rate of Current Performance Measurement System.

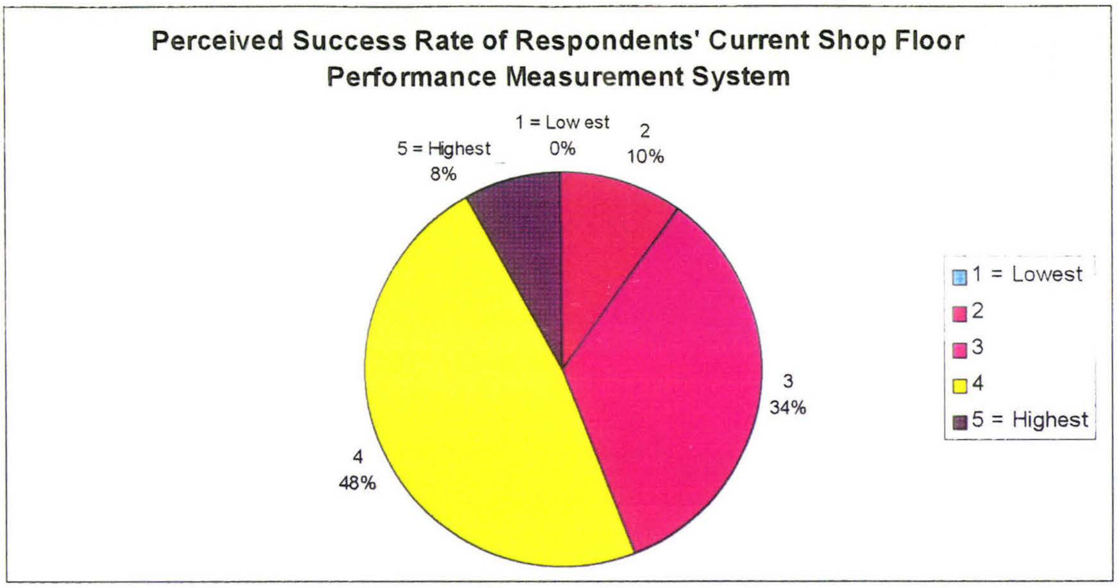


Figure 6.8: Perceived Success Rate of Respondents' Current Shopfloor Performance Measurement System.

There are various opinions and these responses showed different level of shopfloor performance measures understandings. Key notable responses have been underlined in the Appendix B: Respondents' Opinions for Improving Current Shopfloor Performance Measures. The responses suggest, among other things, a need for more company wide improvements, improved communication between various organisational functions and measurements that link shopfloor performance to business objectives.

6.6 Section E: Finance

6.6.1 Objectives

This section is aimed at presenting financial information that would give an indication how the surveyed companies are performing overall. The respondents were asked to indicate (by ticking) on a percentage scale 'Return-on-Investment' and the relative proportion of 'Raw Material', 'Labour' and 'Overhead' costs to 'Sales Revenue'. Two further questions asked the respondents to indicate the past five years' and the next five years' trends for the latter three measures.

See Appendix A: Survey Questionnaire Forms for detailed layout of the questions.

6.6.2 Analysis

Return-on-Investment

The following Table 6.18 shows the spread of ROI classifications. 43 responses were gathered from 56 companies surveyed. One company indicated an ROI of "Greater that 120.1%" which is an extraordinary high result considering survey's average of only "15.1 to 20%" and a median of "10.1 to 15%". This result suggests that the company might have the following possible condition: a niche market, a fast growing market, minimum threat from competition, monopoly, or superior products than competition. The lowest ROI recorded is "Less than –20%". Upon close inspection, it was found that the company was badly effected by the Government's decision to removing the tariffs. These results indicate that most surveyed companies have relatively low return from the investment made.

ROI	Results
Highest	Greater than 120.1%
Median	10.1 to 15%
Average	15.1 to 20%
Lowest	Less than -20%
No. of Respondents	43

Table 6.27: ROI Classifications in the Survey Results.

Further ROI classifications for each plant type is shown in the Appendix E, Table E12: ROI Classifications for Each Plant Type.

Measures / Concerns - ROI Correlation Tests

Four correlation tests were carried out to identify the possibility of a particular set of measure and concerns having any influence in the company's Return-on-Investment (ROI). The tests were carried using Minitab statistics package and by way of Pearson Correlation method. Complete survey data were tabulated and 95% confidence level was used to measure any significant correlation. The results produced mostly insignificant results except for a few measures that have P values less than 5% (i.e. P value less than 5% means there is 95% confidence that the measure has significant impact to company's Return-on-Investment).

Due to measures' and concerns' two sub-divisions, e.g. measures' level of importance and usefulness rating, there were two correlation tests carried out. The first set of tests were to identify any correlation between the assigned level of importance of the measures to the ROI figures. The second set of tests were carried out to identify any correlation between measures' usefulness rating and the ROI figures.

Correlation Test: Measures' Level of Importance and ROI Correlation

The test yielded mostly insignificant results, except for two measures:

1. P1 (i.e. "Conformance to production schedule") with P value 0.020.
2. P20 (i.e. "Labour utilisation") P value 0.043.

The above results suggest that Throughput World measures take precedence in the importance level over Costs World measures.

Correlation Test: Measures' Usefulness Rating and ROI Correlation

The test yielded mostly insignificant results, except for four measures:

1. P8 (i.e. "Downgrade costs") with P value 0.039.
2. P19 (i.e. "Direct labour productivity") with P value 0.028.
3. P21 (i.e. "Labour efficiency") with P value 0.041.
4. P30 (i.e. "Others – company specific") with P value 0.015.

The above results suggest that Costs World measures take precedence in the importance level over Throughput World measures.

Correlation Test: Concerns' Occurrence Rate and ROI Correlation

No significant result was gained.

Concerns' Financial Impact and ROI Correlation

The test yielded mostly insignificant results, except for three measures:

1. C2 (i.e. Too much work in process inventory) with P value 0.045.
2. C9 (i.e. Parts common to several products end up in the products not currently in demand) with P value 0.046.
3. C28 (i.e. Forecasts are often not correct) with P value 0.019.

Additional Information Gathered:

The following tables show additional information gathered from the survey research. The tables show the spread of Materials Costs, Direct Labour Costs and Overhead Costs as a percentage of Sales Revenues. The information gathered do not have direct link to the application of shopfloor measures and these were made available to improve general research knowledge.

➢ Materials Costs as a percentage of Sales Revenues

Materials/Sales	Results
Highest	80.1 to 85%
Median	35.1 to 40%
Average	40.1 to 45%
Lowest	5.1 to 10%
No of Respondents	47

Table 6.28: The Spread of Relative Proportion of Materials Cost from Sales Revenue.

➢ Direct Labour Costs as a percentage of Sales Revenues

Direct Labour/Sales	Results
Highest	65.1 to 70%
Median	10.1 to 15%
Average	15.1 to 20%
Lowest	0.1 to 5%
No of Respondents	48

Table 6.29: The Spread of Direct Labour relative proportion from Sales Revenue.

➢ Overhead Costs as a percentage of Sales Revenues

O'head Costs/Sales	Results
Highest	50.1 to 55%
Median	15.1 to 20%
Average	20.1 to 25%
Lowest	0.1 to 5%
No of Respondents	46

Table 6.30: The Spread Overhead Costs Relative Proportion from Sales Revenue.

6.10 Summary

From the survey research the following summary can be drawn:

1. Company data have been collected for future references if needed.
2. The average management hierarchy of the surveyed companies (i.e. medium to large companies) is 4.
3. Shopfloor staff constitute a much larger proportion of company employees. Sales, Technical and Administration average figures do not differ greatly and their proportions are much smaller than the proportion of shopfloor staff.
4. The surveyed companies were classified into their respective manufacturing categories.
5. The type of scheduling mechanism used in the surveyed companies were classified and ranked.
6. Policies regarding production batch splitting and minimising setups were gathered and classified.
7. Companies were classified into its respective plant types and measures' average score were calculated for ranking purposes.
8. Apart from the traditional classifications of plant types (i.e. A, V, T and Combination of these plant types), there were type I plants identified.
9. The measures were classified into either Throughput World or Cost World measures. These classifications produced mixed results that suggest a "tug of war" between Throughput World and Cost Worlds principles.
10. Level of Importance and Usefulness Rating were calculated for each measure.
11. Measures' Level of Importance have moderate to excellent relationship to measures' Usefulness Rating.
12. Occurrence Rate and Financial Impact were calculated for each production-related concern.
13. Concerns' Occurrence Rate have varying degree of relationships to their Financial Impact.

14. There are a few 'Other' or company specific measures and/or concerns identified in the survey. Most of these have high ratings due to their specificity.
15. There is insignificant correlation between majority of measures and the production related concerns to the companies' ROI.
16. The majority of the respondents rated the shopfloor performance measurement system currently in place to have average to high success rate.
17. Materials and Overhead Costs average figures relative to Sales Revenue are significantly larger than Direct Labour.
18. The respondents were also able to provide input on the likely trend for Materials, Direct Labour and Overhead Costs for the last and next five years. No analysis was carried, however they can be useful to provide general information on the challenges facing the manufacturing industry.

Chapter Seven: Conclusion

7.0 Introduction

This research study has examined a number of issues associated with performance measurement particularly at the lower management level. There are three main parts to this study:

1. An outline of the problems associated with traditional performance measurement.
2. Description of key attributes in a performance measurement system design with particular emphasis in the Theory of Constraints philosophies.
3. The criteria for developing appropriate measures.
4. The survey of shopfloor performance measures application in New Zealand manufacturing companies.

This chapter outlines some of the conclusions that have been drawn from this study.

7.1 An Outline of the Problems Associated with Traditional Performance Measures

Traditional performance measures and the principles behind them are no longer applicable to meet the needs of today's manufacturing organisations. The focus on short-term performance resulted in policies for localised improvements that do not necessarily lead to overall performance. However, this was not entirely due to organisation's internal misconception of the situation. Much of the problems were ignited by external pressures such as from the capital market where a company must perform well financially at all times to maintain and to increase its listed value in the stock market. Without this, the company would be in difficult situation to maintain and search for the much-needed capital. Slight downturn in a few aspects of company operations will no doubt send warning signals to the wary investors. It is for these reasons, company management had to put in place policies for 100% efficiency from every resource available in the company.

The above and coupled with the focus on cost savings required during the times when there were more demands than there were goods are invalid for today's manufacturers where available goods outweighed demand. Today's manufacturing management and other associated attributes for running effective and efficient production operations should be geared towards achieving three competitive dimensions: product, price and responsiveness (see Chapters 1 and 2). Therefore, cost savings principle and its associated measures no longer constitute a manufacturing competitive advantage.

In addition to the above, a Current Reality Tree was drawn to provide useful insight of the negative impact in the use of traditional performance measures on organisation's performance. This illustration utilised cause and effect method.

More detailed outline of the problems associated with traditional measures and the performance measurement techniques are shown in Chapter 2.

7.2 Description of Key Attributes in a Performance Measurement System Design with Particular Emphasis in the Theory of Constraints Philosophies

The performance measurement system covers the entire organisation from the shopfloor level to the top management level. This section has examined the objectives and the attributes that form a performance measurement system. The way measures are applied in management function suggests that measures should be placed in a strategic context as it influences and governs activities and behaviour. A manufacturing performance measurement system should be able to assess the overall level of support that each department provides to the achievement of manufacturing competitive dimensions.

Performance measurement framework as suggested by Kaplan et al (1992) and Lockamy and Cox (1994) would enable the identification of general factors affecting an organisation's performance. The application of principles outlined by Goldratt's Theory of Constraints and Maskell's seven principles of performance measurement design can further enhance the measurement system application especially the management of shopfloor activities.

The Theory of Constraints performance measurement suggests some robust measures that can be defined and function well at top to middle management levels. Throughput, Inventory and Operating Expense can be used to determine where improvement activities should be focused. These three measures combined with a scheduling philosophy with an appreciation to the system's constraint could be used to derive appropriate shopfloor measures.

7.3 The Criteria for Developing Appropriate Shopfloor Performance Measures

TOC synchronisation principles have a primary role in the development of appropriate shopfloor measures, and any other measures. The synchronisation principles were the main foundation for the Drum Buffer Rope scheduling produced to eliminate the system's constraints and their effect to organisation's overall performance. The DBR as it is widely known will help organisation maintain the flow of production activities with the constraint that limits the achievement of the goal and has been investigated to be a robust system. It consisted of a management concept that manages both constraint and non-constraint resources so that each individual resources achieve the company wide objectives effectively and efficiently. The shopfloor measures should be aimed to assist the achievement of carefully developed schedule. The shopfloor measures should not be developed in isolation, as this will induce localised improvements and there will be no standard in which measures' achievements can be compared.

However, at this stage the criteria still requires further development. It is not impossible for additional key elements to be included in the criteria. The cause-effect-cause mechanism that is part of the Future Reality Tree can be used to examine whether a set of solutions would bring about the desired outcomes. These means, the criteria coupled with the Future Reality Tree analysis will complement each other and would help derive appropriate shopfloor measures.

7.4 The Survey of Shopfloor Performance Measures Application in New Zealand Manufacturing Companies

The research survey has produced a series of outcomes that would give some indication on the application of measures in New Zealand. Some of the major conclusions that can be drawn from the analysis are:

- Both Throughput and Cost World measures are applied in the surveyed companies. This suggests that there is a conflict of interest between the need for short-term vision of performance and long term vision of performance.
- The measures and production-related problems have been classified and analysed with varying scores.
- There is not enough evidence that would suggest strong correlation between the type of measures used as well as the production related problems and the resultant ROI.
- A number of other key related production tools and policies have been identified and classified.

Detailed findings from the survey are presented in Chapter 6. More data is required to improve the statistical validation of the survey. There are a number of improvements that can be made from this survey and this warrant further research agenda to be developed.

7.5 Publication from this research

During this research study a paper has been published, its details are as follows:

Wongsonegoro, VT, and Wright, AC, *Shopfloor Performance Measures Survey of New Zealand Manufacturing Companies: Survey Method and Initial Analyses*, Proceedings of the 5th Annual New Zealand Engineering and Technology Postgraduate Student Conference, Palmerston North, New Zealand, November 1998.

Further publications from this research are currently being planned. These include a closer and more detailed examination of the survey results using various applicable methods.

7.6 Summary

In summary this study has presented:

1. An outline of the problems with traditional performance measures.
2. A brief summary of performance measurement system's design. This included a review of some fundamental aspect of a performance measurement system and selected authors' suggestions. The Theory of Constraints performance measurement was covered in detail and majority of the suggestions made are based from this framework.
3. Descriptions of criteria that could be used to derive appropriate shopfloor measures.
4. A proposal of step-by-step method to develop shopfloor measures. This is mostly borrowed from TOC's five focusing steps ongoing improvement scheme.
5. A research agenda to analyse the application of shopfloor measures in the New Zealand manufacturers.
6. Survey results analysis that included assessing the significance of measures and problems, the financial performance and trends, the application of cost world principles.

Chapter Eight: Recommendations

8.0 Introduction

Performance measurement is a rich study area for production and operation management research. It is concerned with all phases of performance measurement from the lowest to highest management hierarchy. The importance of having suitable, practical and appropriate measures to support decision-making processes cannot be denied.

A number of extensions to the work are possible and their brief descriptions are presented in this chapter. For convenience they are categorised into the following areas:

1. The application of TOC-based performance measurement system.
2. Method to develop shopfloor measures.
3. Improvement to the survey result analysis.

8.1 The Application of TOC-based Performance Measurement System

The Theory of Constraint performance measurement principles are some robust techniques in which appropriate shopfloor measures can be conceptualised. The synchronisation principles drove the creation of the Drum Buffer Rope scheduling which can become critical in the development of shopfloor activities and thus the measures that accompany each activity. Chapter 2 and 3 suggest that TOC has the elements that improve performance measurement system significantly and further enhance organisation's synergy.

Agile manufacturing is no longer comes from a predetermined methods in which the manufacturers or the market has control of. It has becoming narrow to the point where everything is controlled by the system's constraint. That is at the point where flexibility and responsiveness are required to combat the effect of a system's constraint. TOC is thus a technology that would give adequate protection for any manufacturing organisation as it focuses improvement effort based on the elimination of the system's constraint and the need to synchronise all activities based on this governing rule.

Although TOC is theoretically sound, its application in New Zealand manufacturing scene has not escalated with the same rate as other technologies such as JIT and TQM. In order to improve the competitiveness of New Zealand manufacturers it would be necessary to apply the TOC philosophies in a wider scale. This can be initiated from the development of case studies in conjunction with small to medium enterprises which there are plenty of them in New Zealand.

8.2 Additional Examination of the Proposed Method to Derive Shopfloor Measures

The proposed step-by-step process to derive appropriate shopfloor measures needs further examination. The method was heavily derived from TOC's Five Focusing Steps and was aimed to provide similar approach in deriving suitable measures. However, the usefulness of this approach has not been tested and thus there is a chance they could mislead the process. TOC's Thinking Process should enable the examination process and has been shown to be useful by Boyd et al (1997) in Chapter 4.

8.3 Explore Other Improvement Ideas from the Survey Research

The survey research gathered some insights into the typical application of shopfloor measures, production related problems and a number of production-related practices. The survey was also useful in gaining some insight on respondents' experience of using particular performance measurement system. However, not enough data was generated and thus the analysis did not produce significant findings on the effect of chosen measures to companies' performance thus, warrant further research to be made.

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Table of Appendices

Appendix A: Survey Questionnaire Form

Shopfloor Performance Measures Survey of NZ Manufacturing Companies

Answering and returning the questionnaire implies your consent to the information being used for the research purposes stated in the information sheet. My discretion and that of my supervisor is guaranteed.

This questionnaire has the objective to identify common problems associated with current shopfloor performance measures. It will enable to establish trends and identify key problem areas which of importance to the development of appropriate performance measures.

If you feel uncomfortable to answer a particular question, please feel free not to answer it. I would appreciate it very much if you could return the incomplete questionnaire in the stamped addressed envelope provided.

The survey questionnaire contains five parts, namely:

Section A - General Enquiries

Section B - Company Profile

Section C - Production and Operation

Section D - Shopfloor Performance Measures

Section E - Finance

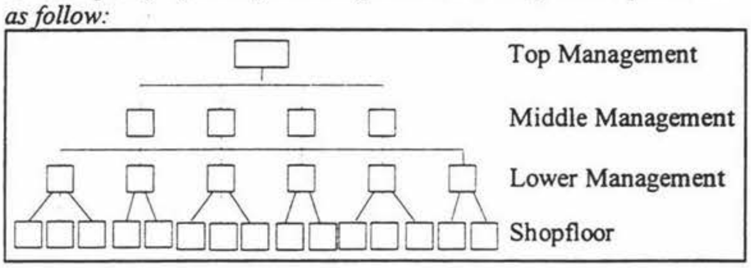
A. GENERAL ENQUIRIES

Company Name:		**Site Name:**	
Address:			
Name of the Respondent:		**Position of the respondent:**	
Contact Information	**Phone:**	**Mobile:**	
	Fax:	**E-mail:**	

B. COMPANY PROFILE

1. How many levels of management currently exist in your company with workers at the shopfloor level being the first level (lower level), workers first line supervisor second and so on, to directors in charge of the site (top level)?

An example of a four layer management hierarchy can be pictured as follow:



Please state number of management levels in your company's hierarchy:	

2. What does your company's personnel consist of?

Please fill in the appropriate box below, you need only to fill out one of the columns (which ever is easiest)

Personnel Type	**Number of People**	**Approx. Percentage (%)**
Executive, e.g. managing director, site manager		
Sales, e.g. marketing, sales engineer, sales support		
Technical, e.g. engineering support, product designer		
Shopfloor, e.g. 1st line operators, machinists		
Administration, e.g. company administrator, secretary		
Total company employee		

C. PRODUCTION AND OPERATION

The questions in this chapter deals with your company's production and operation.

3. Please indicate the manufacturing category of your company by ticking (✓) it in the column labelled ✓. The following categories are as described in New Zealand Scientific and Industrial Classification (NZSIC).

Group 3:	**Manufacturing**	✓
Division 31:	Food, beverage, tobacco	
Division 32:	Textile, apparel and leather goods	
Division 33:	Wood processing and wood product manufacture	
Division 34:	Manufacturing of paper and paper products; printing and publishing	
Division 35:	Manufacture of chemicals and of chemical, petroleum, coal, rubber and plastics products	
Division 36:	Concrete clay, glass, plaster, masonry, asbestos and related mineral product manufacture	
Division 37:	Basic metal industries	
Division 38:	Manufacture of fabricated metal products, machinery and equipment	
Division 39:	Other manufacturing industries	

4. Does your company produce mainly: *(Please tick (✓) one)*

a) small number of products from relatively large number of raw materials? (i.e. Does it have convergent flow of materials through the manufacturing line?)	☐
b) large variety of products from relatively small number of raw materials? (i.e. Does it have divergent flow of materials through the manufacturing line?)	☐
c) number of products from relatively similar number of raw materials? (i.e. Does it have fairly uniform flow of materials through the manufacturing line?)	☐
d) large number of products mainly through assembly combinations of small number of standard components/parts?	☐

5. Does your company make: *(Please tick (✓) one)*

a) entirely to stock?	☐
b) entirely to order?	☐
c) to a mix of both stock and order?	☐

6. If you answered c) in Question 3 please indicate the approximate % of products make to stock and order:

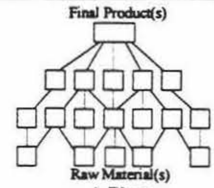
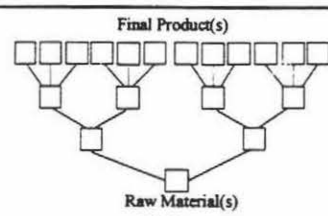
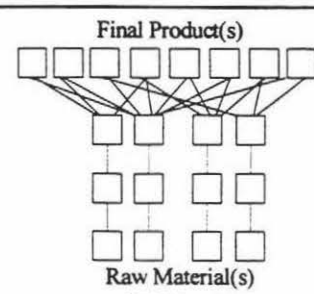
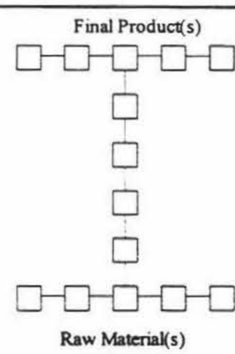
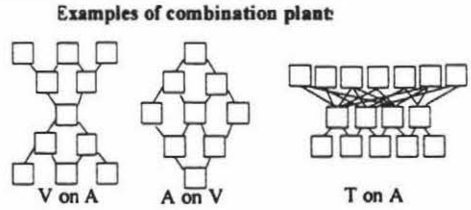
Please fill the appropriate box below, you need only to fill out one of the columns (which ever is easiest)

	% Prod. Vol.	% $ Value
Stock		
Order		

7. Given the description which follow, please attempt to identify the classification which best describes your manufacturing operation.

(Please tick (✓) appropriate box)

☐ A ☐ V ☐ T ☐ I ☐ Combination, Please Specify...

Plant Description	**Plant Layout**
A Plant: Production starts with a huge variety of materials and purchased parts which are machined and assembled into components, sub-assemblies and eventually a finished product.	 **A Plant**
V Plant: Production starts with a single or few raw materials. The product through a series of similar stages, with the product becoming more differentiated at each stage, until a large variety of finished products is available at the end.	 **V Plant**
T Plant: Makes a range of similar products, probably in families or groups, which use a lot of common or similar components. The manufacturing area is organised in units, cells or lines dedicated to a component type. The components come together at assembly where they are combined into much wider range of finished products using different mixes of components and purchased items. Hence the T shape.	 **T Plant**
I Plant: A small number of base materials are used to form a 'raw' product or recipe which then goes through a series of processes without diverging from its original and single destination. It then attracts further materials normally in the form of packaging, which cause a relatively small number of saleable packaged products. The I represents the flow, with materials only being added at start and finish.	 **I Plant**
Combination: There may be combination of any of the above plant types which could exist in an organisation. These can be described using terminology such as "V on A", "A on V", "T on A", etc.	**Examples of combination plant** 

8. What type of scheduling method, if any, is being used at your company?

(Please Tick (✓) Appropriate Box(es))

☐ MRP	☐ JIT	☐ Spreadsheet
☐ MRP II	☐ Kanban Card	☐ None
☐ DBR/OPT	☐ First-Come-First-Serve	☐ Others, Please Specify:..............................
☐ Critical Path	☐ Gantt Chart	....

Please indicate below any modification/alteration made to the scheduling method currently used, e.g. 2-card Kanban.

9. Does your company allow production batch splitting? *(Please tick (✓) one)* ☐ Yes ☐ No ☐ N/A

10. Does your company have a policy of minimising setups? *(Please tick (✓) one)* ☐ Yes ☐ No ☐ N/A

D. SHOPFLOOR PERFORMANCE MEASURES

11. From the following list please indicate the measures currently used in your company for determining shopfloor performance by ticking (✓) it in the column labelled ✓ and proceed to the next two columns. Please write additional measures used that are specific to your company, if not listed, in the space provided.

List of measures used	✓	**Level of Importance** Please circle the number that best describes the level of importance assigned to the measure in your company. Lowest → Highest					**Usefulness Rate** Please circle the number that best describes your view of the usefulness of the measure in achieving the company's goal. Lowest → Highest				
1. Conformance to production schedule		1	2	3	4	5	1	2	3	4	5
2. Process setup times		1	2	3	4	5	1	2	3	4	5
3. Process setup costs		1	2	3	4	5	1	2	3	4	5
4. Production lead times		1	2	3	4	5	1	2	3	4	5
5. Standard hours produced		1	2	3	4	5	1	2	3	4	5
6. Inventory turnover		1	2	3	4	5	1	2	3	4	5
7. Response time		1	2	3	4	5	1	2	3	4	5
8. Downgrade cost		1	2	3	4	5	1	2	3	4	5
9. Scrap cost		1	2	3	4	5	1	2	3	4	5
10.Rework cost		1	2	3	4	5	1	2	3	4	5
11.Cost of quality		1	2	3	4	5	1	2	3	4	5
12.Cost per part		1	2	3	4	5	1	2	3	4	5
13.Overtime		1	2	3	4	5	1	2	3	4	5
14.Conformance to specifications		1	2	3	4	5	1	2	3	4	5
15.Overhead cost		1	2	3	4	5	1	2	3	4	5
16.On-time delivery		1	2	3	4	5	1	2	3	4	5
17.Dollars shipped per period		1	2	3	4	5	1	2	3	4	5
18.Cost reduction/ dollar savings		1	2	3	4	5	1	2	3	4	5
19.Direct labour productivity		1	2	3	4	5	1	2	3	4	5
20.Labour utilisation		1	2	3	4	5	1	2	3	4	5
21.Labour efficiency		1	2	3	4	5	1	2	3	4	5
22.Indirect labour productivity		1	2	3	4	5	1	2	3	4	5
23.Indirect labour efficiency		1	2	3	4	5	1	2	3	4	5
24.Machine efficiency		1	2	3	4	5	1	2	3	4	5
25.Machine activation		1	2	3	4	5	1	2	3	4	5
26.Downtime		1	2	3	4	5	1	2	3	4	5
27.Sales dollars per employee		1	2	3	4	5	1	2	3	4	5
28.Budget/Operating variances		1	2	3	4	5	1	2	3	4	5
29.Quality costs per unit of labour		1	2	3	4	5	1	2	3	4	5
30.(Others, Please Specify)		1	2	3	4	5	1	2	3	4	5

12. Does your company have any concerns of the following type?

Area of concern	**Rate of Occurrence** Please tick (✓) the appropriate box that best describe the rate of occurrence of this particular concern	**Financial Impact** Please tick (✓) the appropriate box that best describe the impact of this particular concern in your company's financial state
1. Too much raw materials inventory	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
2. Too much work in process inventory	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
3. Too much finished goods inventory	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
4. Products do not get sold immediately	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
5. Produce much more than market demands	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
6. Inventory carrying costs are too high	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
7. We have to sell excess finished goods at reduced price	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
8. We have shortages of some sub-component at assembly points in the plant	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
9. Parts common to several products end up in the products not currently in demand	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
10. We have trouble meeting production due dates	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
11. We have trouble meeting customer orders on time	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
12. Unplanned overtime	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
13. We have long production lead times	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
14. There is a lot expediting	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
15. We have to split batches to rush product through for a customer order	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
16. We have considerable amount of scrap/ high re-work	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
17. We have high documentation of activities	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
18. Labour efficiencies/ utilisation are too low	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
19. There is lack of staff able to perform cross functional tasks	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
20. Bottlenecks in our plant shift frequently	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
21. The plant experiences wave-like flow of work	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
22. Resource utilisations are perceived to be unsatisfactory	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
23. Production batch sizes are too large	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
24. We have too many setups	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
25. Process change over (setups) takes too long	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
26. There are walls of distrust between staff at various management levels	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
27. Our estimated sales inflate demands on production	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
28. Forecasts are often not correct	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
29. Sales accuse production of being too slow to respond	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
30. The sales department expect unrealistic delivery times	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
31. There is a "protect your rear parts" mentality among staff members	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large
32. Inter-departmental conflict is common	☐ Never ☐ Sometimes ☐ Often	☐ Small ☐ Medium ☐ Large

33. (others please specify)	☐ Never ☐ Sometimes ☐ Often	☐Small ☐Medium ☐Large

13. How would you rate the success of the current shopfloor performance measurement system in assisting the company to achieve its objectives? and why?

(Please circle the appropriate number)

Lowest		→		Highest
1	2	3	4	5

Please state your reasons in the box below:

14. List the main points that in your opinion need to be improved in order for current shopfloor performance measures to better help the workforce achieve the company's objectives?

Please state your opinion in the box below:

E. FINANCE

Note: The following questions relate to your company's financial state, I would like to remind you that confidentiality of your specific information is guaranteed.

15. What ROI is typical of your company's result in the last five years?

(Please tick (✓) on the nearest grade)

Less than -20% -20% -10 0 10 20 30 40 50 60 70 80 90 100 110 120% Greater than 120%

16. Based on Sales Revenue please indicate approximate proportion for the following major cost categories.

(Please tick (✓) on the nearest grade)

Materials as a % of Sales Revenue

0 10 20 30 40 50 60 70 80 90 100%

Direct Labour as a % of Sales Revenue

0 10 20 30 40 50 60 70 80 90 100%

Overhead Costs as a % of Sales Revenue

0 10 20 30 40 50 60 70 80 90 100%

17. Has the relative proportions in Question 16 changed in any way in the last five years (e.g. Materials dropped, Labour constant, Overhead up)?

(Please tick (✓) appropriate box)

Materials	☐ Dropped	☐ Constant	☐ Increased
Direct Labour	☐ Dropped	☐ Constant	☐ Increased
Overhead Costs	☐ Dropped	☐ Constant	☐ Increased

18. In the next five years, do you expect the above trends to: *(Please tick (✓) appropriate box)*

☐ Reverse ☐ Continue ☐ Remain stable

Thank you for your time. I appreciate your help with my research project.

A copy of the summary of the findings is available upon request from my chief supervisor, Mr. A.C.Wright.

Please place the completed questionnaire in the stamped addressed envelope provided, and mail it to me today.

Appendix B: Respondents' Opinions for Methods to Improving Current Shop Floor Performance Measures

The survey respondents were required to give their comments on the following question:

Q14: List the main points that in your opinion need to be improved in order for current shopfloor performance measures to better help the workforce achieve the company's objectives?

Their comments were presented as follows:

1. Better computer system to be able to measure yield per operation, report more on production variance, i.e. quantity dollars to schedule, delivery on time.
2. Sales/Marketing need to understand Production/Manufacturing as too often they give ridiculous delivery times to customers.
3. A cultural change is required to bring about an attitude change from people considering jobs as "right" to a co-operative environment where staff work together to achieve a unified objective.
4. More KPI by Team, flexible working.
5. Have difficulty in communicating requirements.
6. Forecast of client requirements, the report responses clearly reflect the operation, a very service oriented manufacturer faced daily with unknown delivery & pattern requirement. This is caused by a need to carry to 3000 SKUs to satisfy client (& competitors) demands.
7. A lot of it is done on spreadsheets. There is a need to incorporate it into our manufacturing system & integrate it with the financial system.
8. Sales
9. More technology, marketing, sales training.
10.Shopfloor people to be awarded for KRA achievement, reduce barriers between different posts of the process: greater seamless process.
11.Team work, ownership of responsibility.
12.Better education level about the economics of a company.
13.Mix adjusted benchmarking (being rolled out now).
14.Clearly standard & consistent workload would assist in better measuring workflow performance. Also our products carry which also means it is difficult to measure.
15.Better two way communications between plant & sales/marketing; An understanding of the economic value added model & their ability to impact its performance.
16.Better understanding and training in Deming principles.
17.Forecasting of sales to be translated into the placing of production orders on the manufacturing plant.
18.Give all staff members more information about the job.
19.Staff training.
20.Work groups need to be able to contribute more, middle management has to accept

the shopfloor can contribute, despite the work being tedious. Work groups will then be prepared to contribute more to continuous improvement/ personal benchmarking.
21.Production planning.
22.More understanding from customers, more forward notice of jobs from customers.
23.Greater ownership and decision making at shopfloor level.
24.To know the direction of company, to keep exchanging opinions, to inform customers requirements timely.
25.Need to define standard times for tasks to better calculate capacities.
26.Measurements that link shopfloor performance to business objectives.
27.Be able to have work teams deciding on their own KPI (Key Performance Indicators) rather than being driven from top down.
28.Amount of rework, efficiency of manufacturing, throughput of products in production, on time deliveries.
29.Allowances need to be factored in the relevance of the age of the equipment people are using, i.e. new vs. old; management use of statistical information.
30.Greater recognition of the need for stability in operations, developing the ability to the flexible and low in cost unit set ups and in production process cost to get the product to the customer before anyone else can.
31.Increased communication; Increased staff training; Increased accountability.
32.Maintain a high level of checks and measurements and/or ensuring quality standards are met.
33.New machines to reduce labour intensive tasks. Better scheduling procedures that are more flexible and responsive.
34.Firmly establish skill-based pay; Eliminate Over Time; Develop gain sharing - with appropriate and achievable targets.
35.Integrated enterprise software
36.Better planning increases productivity.
37.Quality. It would be fantastic to reduce set ups and set up times. Large runs are great, market determine this through orders. We need more capacity, Now!
38.Higher education level, more new ideas.
39.Clear communication between senior and middle management, and parent company and administration staff, clear communication of company wide goals.
40.Through high performance team development, the shopfloor teams will further develop their performance measures, include them in their own Operating Plans and be accountable for them at quarterly governance reviews. We also have a continuous improvement incentives variable pay scheme.
41.Better communication of objectives and expectations so the workforce can take responsibility for achieving the objectives; better follow-up and handling of these workers who refuse to accept responsibility.
42.Accurate measurement of raw and packaging material usage; A simple measure for the total cost of poor quality; More emphasis placed on increasing fixed asset utilisation.
43.Accuracy of data; Automatic data collection; Attention to positives not just negatives; Results clearly displayed and communicated; Clear explanation of measurable and business effects.
44.Longer Runs: very jobbing types of work due to shorter lead times available in the industry; Inter departmental Barriers: with the current structure the silo mentality is causing major issues.
45.System is working well - evidenced by low fault level bettered only by TMC Japan in its fully automated plants. However fine-tuning of all of our system is always

being carried out.
46.We believe with the CAPRI system in place, we will have all information required empowering our people.
47.Our production & management KPIs continue to go through adjustment & improvement. However, after 10-20 years work in this area it is more of gradual move. System is slowly being expanded into more tangible aspects such as staff skills & ROI for training.

Appendix C: Survey Research's Introductory Letter

Palmerston North
(Day & Dates)

(Massey Letterhead to
be inserted here)

(Respondent's Details-
to be inserted here)

Dear Respondent,

Project: Shop Floor Performance Measures Survey of New Zealand Manufacturing Companies

My name is Lery Wongsonegoro and I am currently studying for a Master of Technology in Manufacturing and Industrial Technology through Massey University. I am interested in the fact that many performance measures used in industry do not suit the needs of modern manufacturing organisations and thus they have the potential to mislead managers when making decisions.

I am undertaking research aimed at benefiting New Zealand manufacturing organisations through the development of criteria for shopfloor measures that meet today's business challenges. As part of the research component of my thesis, I am undertaking a survey with the following objectives:

1. To identify common problems associated with using current shopfloor performance measures in New Zealand manufacturing organisations.
2. To assist New Zealand manufacturing companies, where possible, to benchmark their activities and become more aware of possible avenues for improvement with regard to the measures of shopfloor performance.

The following points will assist you to complete this questionnaire:

1. It is envisaged that the Chief Executive Officer, Production Manager or a member of the Senior Management team familiar with all the site's operations is the most appropriate person to complete this questionnaire.
2. The questions are very straight forward and the whole questionnaire should only take about 30 minutes to complete.

3. My discretion and that of my chief supervisor, is guaranteed. Answering and returning the questionnaire implies your consent to the information being used for the research purposes stated above.
4. Participants of this survey are selected from the top 300 manufacturing companies as listed in the Kompass - The Authority In New Zealand Business CD-ROM.
5. I will be the only person involved in collating and analysing the information received. Once completed the returned survey forms will be destroyed. Data will be stored in my computer's database only with safety Personal Identification Number (PIN) installed. Only summary information will be published and there will be no mention of specific source of details.
6. In order to complete my project in time to meet University deadlines, I need to receive your reply no later than **Friday, 29 May 1998**. Please use the stamped addressed envelope provided to return the questionnaire.
7. The summary information of the survey will be available to the participating companies upon request from my chief supervisor.

Should you have any questions regarding the questionnaire, you can contact either my chief supervisor, Mr. AC Wright or myself via any of the following methods:

V.T. (Lery) Wongsonegoro
Postgraduate Lab: (06) 350 4422
Mobile: (025) 408 428 (after hours)
e-mail: Valery.Wongsonegoro.1@uni.massey.ac.New Zealand

Mr. AC(Alan) Wright
Work: (06) 350 4090
Fax: (06) 350 5604
e-mail: ACWright@massey.ac.New Zealand

I look forward to your assistance in this project and thank you for taking the time to complete this survey.

Yours Sincerely,

V.T. (Lery) Wongsonegoro
Institute of Technology and Engineering
College of Science
Massey University
Private Bag
Palmerston North

Appendix D: Traditional Manufacturing Measures

Date:	Tuesday, 2 September 1997
To:	Alan C. Wright
Topic:	This document contained a list of traditional manufacturing measures and their descriptions as found in a study by Edwards (1986).
Source:	The information contained in this appendix were extracted from James B. Edwards's *The use of Performance Measures* (National Association of Accountants, Montvale, New Jersey, 1986).
Note:	Information contained in this document was used to develop the survey questionnaire and was useful in describing some of the traditional manufacturing measures.

A. Type of Measures and Their Descriptions

1. Units-of-Output Variance
Message: Measures deviation from physical plans (goals).

2. Value-of-Output Variance
Message: Measures deviation from financial plans (goals).
Comments: Budgeted sales value of output can be based on a static or flexible plan. If a firm chooses a flexible-budget approach, the budgeted sales value of output must be based on actual physical output.

3. Production-Quantity (Output) Impact Variance
Message: Measures approximate overall financial effects of fluctuations in volume as compared to plan.
Caution: The measure does not focus on individual product results because all physical units are affected at a single overall weighted average budgeted contribution margin per unit. Accuracy is achieved only if the original product mix is maintained as planned. As an alternative, calculate variance by individual products using the budgeted contribution for each product.

4. Production-Mix (Output) Impact Variance
Message: Measures the financial impact of the deviation from the planned average contribution margin per unit associated with a change in the units produced of a particular product.
Caution: This method produces a weighted-average effect.

5. Responsibility by Cost Centre
Message: Identifies costs according to responsibility.
Alternatives: A *profit centre* matches revenues with related expenses. In an *investment centre* managers have responsibility for both profits and the resources vested with the center.

6. Imputed-Cost Yield
Message: Measures the economic impact of a particular event based on the best viable alternative use of the resources employed.
Comment: Non routine outlay costs may be included in the denominator.

7. Material-Price (Input) Variance
Message: Measures the financial impact of the difference between actual unit prices and budgeted or "bench mark" (standard) unit prices affected by the related quantity of units.
Comments: Some firms calculate this variance at the point the goods are received from the supplier and placed into raw materials and parts inventory. These firms associate the variance with the purchasing function. Others calculate the variance as the units are entered into the production process. These firms identify the variance with the ultimate use of the goods. Still other firms which desire to detect the variance prior to the purchase calculate the variance based on the potential supplier's current price quote. Based on this information, the firm can either seek other suppliers, locate a substitute material or part, or accept the price difference. If the firm accepts the price difference, it is in a position to change the standard and/or increase its selling price to reflect the change and then pass the impact through to customers.
Caution: Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

8. Materials-Quantity (Input) Variance
Message: Measures the financial impact of the difference between actual usage and budgeted or "bench mark" (standard) usage calculated at standard price per nit of measure.
Comments: This measure is alternatively referred to as materials-usage *variance.*
Caution: Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

9. Materials-Mix (Input) Variance
Message: Measures the financial impact of the deviation from the planned average price of inputs per unit associated with a change in the units used to produce a particular product.
Comments: *Materials mix* is the relative proportion or combination of the various ingredients of direct materials or components used to produce a particular product.

When a firm alters the balance of this mix in actual production, a materials-mix variance results.

Caution: This method produces a weighted-average effect. Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard mix and favourable denotes greater than standard mix.

10. Materials-Yield (Input) Variance

Message: Measures approximate overall financial effects of fluctuations in materials yield as compared to plan.

Comments: *Materials yield* is the quantity of a particular product produced from a predetermined (standard) combination and amount of the various direct materials or components used to produce the product. When a firm alters the amount of any material used in actual production, a materials-yield variance results.

Caution: The measure does not focus on individual input results because all physical units are affected at a single overall weighted average budgeted price per unit. Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

11. Materials-Substitution (Input) Variance

Message: Measures the financial impact of using substitute materials in lieu of the original materials, calculated at budgeted (standard) prices for each material.

Comment: Give a choice, managers should choose the combination of materials that results in the same product quality and the lowest overall cost.

Caution: The measure does not focus on individual input results because all physical units are affected at a single overall weighted average budgeted price per unit. Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

12. Labour-Rate (Input) Variance

Message: Measures the financial impact of the difference between actual labour pay rates and budgeted or "bench mark" (standard) pay rate affected by the related quantity of units (hours).

Comments: Assuming a firm with a fixed pay scale (labour contract), this variance could signal a change in labour-mix, labour substitution, or a deviation in outing. Under these circumstances, the labour rate variance should alert management that a deviation from the labour plan has occurred.

Caution: Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

13. Labour-Efficiency (Input) Variance

Message: Measures the financial impact of the difference between actual hours and budgeted or "bench mark" (standard) hours, calculated at standard rate per unit of measure.

Caution: Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and favourable denotes greater than standard.

14. Labour-Mix (Input) Variance

Message: Measures the financial impact of the deviation from the planned average pay rates per hour associated with a change in the hours need to produce a particular product.

Comments: *Labour Mix* is the relative proportion or combination of the various classes of direct labour used to produce a particular product. When a firm alters the balance of this mix in actual production, a labour-mix variance results.

Caution: This method produces weighted-average effect. Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard mix and unfavourable denotes greater than standard mix.

15. Labour-Yield (Input) Variance

Message: Measures approximate overall financial effects of fluctuations in labour yield as compared to plan.

Comments: *Labour Yield* is the quantity of a particular product produced from a predetermined (standard) combination of hours of the various classes of labour used to produce the product. When a firm alters the hours of any class of labour used in actual production, a labour-yield variance results.

Caution: The measure does not focus on individual input result because all labour hours re affected at a single overall weighted average budgeted rate per hour. Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

16. Labour-Substitution (Input) Variance

Message: Measures the financial impact of using substitute labour in lieu of the original labour, calculated at budgeted (standard) rates for each class of labour.

Comment: Given a choice, managers should choose the combination of labour that results in the same product quality and the lowest overall cost.

17. Overhead Analysis: Two-Way

Message: Measures the financial impact of the difference between actual overhead costs and standards.

Comments: When a firm estimates the activity level for the production volume variance, it can see a number of approaches. For example:

- *Theoretical capacity* - Output is produced efficiently 100% of the time. There is very little support for this approach.
- *Practical capacity* - Output is produced efficiently after adjusting for noncontrollable factors such as normal downtime, holiday shutdowns and the like. This approach focuses on the effect of idle capacity. It provides some guidance for competitive pricing situations.
- *Normal Volume* - Output is produced efficiently at average levels necessary to meet sales and inventory needs for several years (three to five years). This approach, based on expected results, tends to stabilise product costs from year to year.
- *Expected annual capacity* - Output is produced efficiently at average levels necessary to meet sales and inventory needs for the current year. This approach, based on expected results in the near future, tends to cost products at close to actual costs.

Caution: Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

18. Overhead Analysis: Three-Way

Message: Measures the financial impact of the difference between actual overhead costs and standards.

Comments: The three-way method goes one step further than the two-way method by introducing the flexible budget for actual inputs. This separates the variable overhead budget variance into a spending variance and an efficiency variance.

Caution: Favourable and unfavourable do not necessarily mean good and bad, respectively. Favourable denotes less than standard and unfavourable denotes greater than standard.

19. Total-Productivity Ratio

Message: Measures the relationship of dollar inputs to dollar outputs.

Comments: Outputs and inputs must be stated in common units, generally constant dollars, to derive meaningful relationships. By adjusting all dollar amounts to a base-period value, productivity ratios become comparable from period to period. Sales value of output is used rather than actual sales because productivity is a ratio of ability to convert inputs to outputs during a given time period. All inputs included should be related to producing the recognised outputs. For example, extraordinary gains and losses should not be included in the output unless some input was consumed in producing them. Typically, interest income and dividends received should be included in the output for the period, because capital inputs are used to produce them.

20. Partial-Productivity Gain (Loss)

Message: Measures the productivity changes between two time periods for a single input in terms of quantity measurements.

Caution: A change in quality of some other input could affect the productivity measurement of the subject input. For example, the substitution of a higher quality raw material could decrease the person hours required to produce the output. However, if the improved labour productivity was more than offset by the increased cost of the better quality raw material, then the labour productivity gain could be misleading. *Partial Productivity* that does not consider the overall effects of all factors should be avoided.

Appendix E: Survey Results

Table E1: Measures' Level of Importance by Average Score – Individual Plants.

Plant	A			V			T			I			Combination		
Rank	Measures	Aver	T/C	Measures	Aver	T/C	Measures	Aver	T/C	Measures	Aver	T/C	Measures	Aver	T/C
1	Conformance to specifications	5.00	T	Others (company specific)	5.00		Others (company specific)	5.00		Others (company specific)	5.00		Others (company specific)	5.00	
2	On-time delivery	4.63	T	Conformance to specifications	4.67	T	On-time delivery	4.60	T	Conformance to specifications	4.71	T	Conformance to specifications	4.75	T
3	Cost per part	4.40	C	On-time delivery	4.61	T	Conformance to specifications	4.56	T	Machine activation	4.67	C	On-time delivery	4.71	T
4	Direct labour productivity	4.14	C	Response time	4.42	T	Direct labour productivity	4.38	C	On-time delivery	4.60	T	Dollars shipped per period	4.33	T
5	Conformance to production schedule	4.00	T	Budget/Operating variances	4.41	C	Conformance to production schedule	4.25	T	Machine efficiency	4.50	C	Labour efficiency	4.29	C
6	Standard hours produced	4.00	C	Direct labour productivity	4.38	C	Standard hours produced	4.00	C	Budget/Operating variances	4.50	C	Direct labour productivity	4.25	C
7	Cost of quality	4.00	C/T	Machine efficiency	4.27	C	Cost per part	4.00	C	Process setup costs	4.00	C	Budget/Operating variances	4.13	C
8	Overhead cost	4.00	C	Cost reduction/ dollar savings	4.13	C	Dollars shipped per period	4.00	T	Cost reduction/ dollar savings	4.00	C	Labour utilisation	3.86	C
9	Cost reduction/ dollar savings	4.00	C	Production lead times	4.07	C/T	Cost reduction/ dollar savings	3.86	C	Downtime	4.00	C/T	Inventory turnover	3.83	C/T
10	Labour utilisation	4.00	C	Scrap cost	4.07	C/T	Budget/Operating variances	3.75	C	Response time	3.67	C/T	Response time	3.83	C/T
11	Labour efficiency	4.00	C	Downtime	3.95	C/T	Labour efficiency	3.71	C	Dollars shipped per period	3.67	T	Cost per part	3.75	C
12	Production lead times	3.83	T	Labour utilisation	3.93	C	Overhead cost	3.63	C	Conformance to production schedule	3.57	T	Overhead cost	3.75	C
13	Machine efficiency	3.83	C	Dollars shipped per period	3.91	T	Overtime	3.57	C	Scrap cost	3.33	C/T	Cost reduction/ dollar savings	3.63	C
14	Dollars shipped per period	3.80	T	Conformance to production schedule	3.89	T	Inventory turnover	3.50	C/T	Indirect labour efficiency	3.33	C	Conformance to production schedule	3.57	T
15	Downtime	3.80	C/T	Overhead cost	3.83	C	Cost of quality	3.50	C/T	Overhead cost	3.20	C	Standard hours produced	3.50	C
16	Response time	3.67	T	Rework cost	3.80	C	Response time	3.43	C/T	Indirect labour productivity	3.20	C	Overtime	3.50	C
17	Budget/Operating variances	3.67	C	Labour efficiency	3.71	C	Rework cost	3.38	C	Process setup times	3.00	C/T	Machine efficiency	3.33	C
18	Rework cost	3.60	C/T	Cost of quality	3.67	C	Downtime	3.33	C/T	Inventory turnover	3.00	C/T	Downtime	3.33	C/T
19	Inventory turnover	3.50	C/T	Inventory turnover	3.61	C/T	Scrap cost	3.29	C/T	Rework cost	3.00	C	Production lead times	3.29	T
20	Indirect labour efficiency	3.40	C	Overtime	3.60	C	Process setup times	3.00	C/T	Labour utilisation	3.00	C	Rework cost	3.25	C
21	Machine activation	3.40	C	Downgrade cost	3.58	C	Production lead times	3.00	T	Labour efficiency	3.00	C	Indirect labour productivity	3.17	C
22	Process setup times	3.33	C/T	Cost per part	3.50	C	Labour utilisation	3.00	C	Direct labour productivity	2.83	C	Process setup times	3.00	C/T
23	Scrap cost	3.20	C/T	Standard hours produced	3.42	C	Quality costs per unit of labour	3.00	C	Production lead times	2.80	T	Scrap cost	2.88	C/T
24	Downgrade cost	3.00	C	Machine activation	3.40	C	Machine efficiency	2.67	C	Overtime	2.67	C	Sales dollars per employee	2.83	C
25	Sales dollars per employee	3.00	C	Process setup costs	3.33	C	Sales dollars per employee	2.50	C	Sales dollars per employee	2.50	C	Indirect labour efficiency	2.71	C
26	Overtime	2.80	C	Indirect labour productivity	3.30	C	Indirect labour productivity	2.33	C	Standard hours produced	2.40	C	Cost of quality	2.50	C
27	Indirect labour productivity	2.80	C	Quality costs per unit of labour	3.22	C	Process setup costs	2.29	C	Downgrade cost	2.33	C	Quality costs per unit of labour	2.40	C
28	Process setup costs	2.71	C	Process setup times	3.20	C/T	Machine activation	2.20	C	Cost of quality	2.33	C/T	Machine activation	2.33	C
29	Quality costs per unit of labour	2.40	C	Indirect labour efficiency	3.20	C	Indirect labour efficiency	2.17	C	Cost per part	2.25	C	Downgrade cost	2.25	C
30	Others (company specific)	0.00		Sales dollars per employee	2.56	C	Downgrade cost	2.00	C	Quality costs per unit of labour	1.67	C	Process setup costs	2.00	C

Table E2: Measures' Usefulness Rating by Average Score – Individual Plants.

Plant	A		V		T		I		Combination	
Rank	Measures	Aver	Measures	Aver	Measures	Aver	Measures	Aver	Measures	Aver
1	Conformance to specifications	4.88	Others (company specific)	5.00	Conformance to specifications	4.78	Others (company specific)	5.00	Others (company specific)	5.00
2	On-time delivery	4.38	On-time delivery	4.56	On-time delivery	4.40	On-time delivery	4.75	On-time delivery	4.71
3	Overhead cost	4.25	Conformance to specifications	4.44	Standard hours produced	4.29	Budget/Operating variances	4.29	Conformance to specifications	4.63
4	Conformance to production schedule	4.20	Budget/Operating variances	4.41	Direct labour productivity	4.25	Cost reduction/ dollar savings	4.25	Dollars shipped per period	4.00
5	Standard hours produced	4.17	Production lead times	4.27	Budget/Operating variances	4.25	Conformance to specifications	4.17	Cost reduction/ dollar savings	3.88
6	Cost reduction/ dollar savings	4.17	Response time	4.25	Cost of quality	4.14	Production lead times	4.00	Direct labour productivity	3.88
7	Production lead times	4.00	Direct labour productivity	4.06	Conformance to production schedule	4.00	Scrap cost	4.00	Budget/Operating variances	3.88
8	Dollars shipped per period	4.00	Machine efficiency	4.06	Others (company specific)	4.00	Cost of quality	4.00	Conformance to production schedule	3.83
9	Downtime	4.00	Scrap cost	4.00	Overhead cost	3.88	Machine efficiency	4.00	Overhead cost	3.75
10	Direct labour productivity	3.86	Downtime	3.95	Inventory turnover	3.75	Downtime	4.00	Machine efficiency	3.67
11	Labour efficiency	3.86	Cost reduction/ dollar savings	3.94	Production lead times	3.71	Conformance to production schedule	3.80	Indirect labour efficiency	3.57
12	Machine efficiency	3.83	Labour efficiency	3.93	Scrap cost	3.71	Response time	3.50	Cost per part	3.50
13	Labour utilisation	3.71	Dollars shipped per period	3.91	Rework cost	3.71	Machine activation	3.50	Indirect labour productivity	3.50
14	Downgrade cost	3.67	Conformance to production schedule	3.76	Cost per part	3.71	Labour efficiency	3.40	Downtime	3.50
15	Rework cost	3.60	Overhead cost	3.67	Labour utilisation	3.71	Inventory turnover	3.25	Labour efficiency	3.43
16	Cost per part	3.60	Rework cost	3.63	Response time	3.67	Indirect labour productivity	3.25	Standard hours produced	3.33
17	Machine activation	3.60	Labour utilisation	3.57	Machine efficiency	3.67	Direct labour productivity	3.20	Cost of quality	3.33
18	Inventory turnover	3.57	Downgrade cost	3.55	Dollars shipped per period	3.60	Process setup times	3.00	Sales dollars per employee	3.33
19	Cost of quality	3.57	Cost of quality	3.53	Cost reduction/ dollar savings	3.57	Process setup costs	3.00	Inventory turnover	3.17
20	Indirect labour productivity	3.40	Inventory turnover	3.53	Labour efficiency	3.57	Standard hours produced	3.00	Response time	3.17
21	Indirect labour efficiency	3.40	Machine activation	3.50	Downtime	3.50	Rework cost	3.00	Overtime	3.17
22	Response time	3.33	Cost per part	3.42	Overtime	3.33	Dollars shipped per period	3.00	Labour utilisation	3.14
23	Budget/Operating variances	3.33	Indirect labour productivity	3.40	Quality costs per unit of labour	3.00	Labour utilisation	3.00	Scrap cost	3.13
24	Scrap cost	2.80	Indirect labour efficiency	3.30	Indirect labour productivity	2.83	Overtime	2.60	Rework cost	3.13
25	Overtime	2.80	Overtime	3.27	Sales dollars per employee	2.83	Overhead cost	2.50	Production lead times	3.00
26	Process setup times	2.67	Process setup costs	3.25	Downgrade cost	2.75	Indirect labour efficiency	2.50	Quality costs per unit of labour	3.00
27	Sales dollars per employee	2.60	Standard hours produced	3.17	Process setup times	2.67	Cost per part	2.33	Downgrade cost	2.50
28	Process setup costs	2.43	Process setup times	3.14	Indirect labour efficiency	2.67	Downgrade cost	2.00	Process setup times	2.33
29	Quality costs per unit of labour	2.40	Quality costs per unit of labour	3.11	Machine activation	2.40	Sales dollars per employee	1.67	Machine activation	2.33
30	Others (company specific)	0.00	Sales dollars per employee	2.89	Process setup costs	2.00	Quality costs per unit of labour	1.00	Process setup costs	1.40

Table E3: Concerns' Rate of Occurrence by Average Score – Individual Plants.

Plant	A		V		T		I		Combination	
Rank	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver
1	Forecasts are often not correct	2.25	Others (company specific)	3.00	Forecasts are often not correct	2.40	Forecasts are often not correct	2.44	Forecasts are often not correct	2.56
2	Inventory carrying costs are too high	2.00	Forecasts are often not correct	2.42	Unplanned overtime	2.33	There is lack of staff able to perform cross functional tasks	2.22	We have long production lead times	2.20
3	Products do not get sold immediately	1.88	Products do not get sold immediately	2.37	We have high documentation of activities	2.25	We have high documentation of activities	2.11	The sales department expect unrealistic delivery times	2.20
4	We have shortages of some sub-component at assembly points in the plant	1.88	The plant experiences wave-like flow of work	2.22	We have trouble meeting production due dates	2.20	Inter-departmental conflict is common	2.11	There is a lot expediting	2.13
5	We have trouble meeting customer orders on time	1.88	We have high documentation of activities	2.11	We have shortages of some sub-component at assembly points in the plant	2.11	The plant experiences wave-like flow of work	2.00	We have too many setups	2.13
6	We have long production lead times	1.88	Too much finished goods inventory	2.05	Labour efficiencies/ utilisation are too low	2.11	Process change over (setups) takes too long	2.00	Too much raw materials inventory	2.11
7	The plant experiences wave-like flow of work	1.88	Inventory carrying costs are too high	2.05	The plant experiences wave-like flow of work	2.11	Too much raw materials inventory	1.89	Products do not get sold immediately	2.10
8	Process change over (setups) takes too long	1.88	We have trouble meeting production due dates	2.00	Too much raw materials inventory	2.10	There are walls of distrust between staff at various management levels	1.89	Too much finished goods inventory	2.00
9	The sales department expect unrealistic delivery times	1.86	We have trouble meeting customer orders on time	2.00	We have considerable amount of scrap/ high re-work	2.00	Sales accuse production of being too slow to respond	1.89	Unplanned overtime	2.00
10	Too much raw materials inventory	1.75	There is a lot expediting	2.00	There is lack of staff able to perform cross functional tasks	2.00	There is a "protect your rear parts" mentality among staff members	1.89	Resource utilisations are perceived to be unsatisfactory	2.00
11	We have trouble meeting production due dates	1.75	We have too many setups	2.00	We have too many setups	2.00	We have trouble meeting customer orders on time	1.78	Inventory carrying costs are too high	1.90
12	We have high documentation of activities	1.75	Sales accuse production of being too slow to respond	2.00	There are walls of distrust between staff at various management levels	2.00	We have long production lead times	1.78	We have trouble meeting production due dates	1.90
13	We have too many setups	1.75	Unplanned overtime	1.95	We have trouble meeting customer orders on time	1.90	We have considerable amount of scrap/ high re-work	1.78	Produce much more than market demands	1.89
14	Sales accuse production of being too slow to respond	1.67	There is lack of staff able to perform cross functional tasks	1.95	Inventory carrying costs are too high	1.89	We have too many setups	1.78	Our estimated sales inflate demands on production	1.89
15	Too much finished goods inventory	1.63	Process change over (setups) takes too long	1.95	Resource utilisations are perceived to be unsatisfactory	1.89	Inventory carrying costs are too high	1.67	We have shortages of some sub-component at assembly points in the plant	1.80

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16	Unplanned overtime	1.63	There is a "protect your rear parts" mentality among staff members	1.95	Process change over (setups) takes too long	1.89	We have trouble meeting production due dates	1.67	We have trouble meeting customer orders on time	1.80
17	We have to split batches to rush product through for a customer order	1.63	We have to split batches to rush product through for a customer order	1.94	We have to split batches to rush product through for a customer order	1.88	Unplanned overtime	1.67	Labour efficiencies/ utilisation are too low	1.80
18	Our estimated sales inflate demands on production	1.63	Our estimated sales inflate demands on production	1.94	The sales department expect unrealistic delivery times	1.88	Labour efficiencies/ utilisation are too low	1.67	The plant experiences wave-like flow of work	1.78
19	We have to sell excess finished goods at reduced price	1.57	There are walls of distrust between staff at various management levels	1.89	There is a lot expediting	1.83	Our estimated sales inflate demands on production	1.67	Process change over (setups) takes too long	1.78
20	There is a lot expediting	1.57	The sales department expect unrealistic delivery times	1.89	Bottlenecks in our plant shift frequently	1.78	Too much work in process inventory	1.56	There are walls of distrust between staff at various management levels	1.78
21	There is a "protect your rear parts" mentality among staff members	1.57	Too much raw materials inventory	1.89	Inter-departmental conflict is common	1.78	Too much finished goods inventory	1.56	Sales accuse production of being too slow to respond	1.78
22	Produce much more than market demands	1.50	Too much work in process inventory	1.89	Products do not get sold immediately	1.75	Products do not get sold immediately	1.56	There is lack of staff able to perform cross functional tasks	1.70
23	There is lack of staff able to perform cross functional tasks	1.50	Produce much more than market demands	1.84	We have long production lead times	1.75	Produce much more than market demands	1.56	Production batch sizes are too large	1.63
24	Bottlenecks in our plant shift frequently	1.50	Labour efficiencies/ utilisation are too low	1.84	Sales accuse production of being too slow to respond	1.71	There is a lot expediting	1.56	We have high documentation of activities	1.60
25	Resource utilisations are perceived to be unsatisfactory	1.50	Inter-departmental conflict is common	1.84	Too much finished goods inventory	1.67	Resource utilisations are perceived to be unsatisfactory	1.56	There is a "protect your rear parts" mentality among staff members	1.60
26	We have considerable amount of scrap/ high re-work	1.38	Bottlenecks in our plant shift frequently	1.79	Our estimated sales inflate demands on production	1.67	The sales department expect unrealistic delivery times	1.56	Inter-departmental conflict is common	1.60
27	Labour efficiencies/ utilisation are too low	1.38	Resource utilisations are perceived to be unsatisfactory	1.79	Too much work in process inventory	1.63	We have to sell excess finished goods at reduced price	1.50	Parts common to several products end up in the products not currently in demand	1.56
28	There are walls of distrust between staff at various management levels	1.38	We have to sell excess finished goods at reduced price	1.74	There is a "protect your rear parts" mentality among staff members	1.63	Production batch sizes are too large	1.44	Bottlenecks in our plant shift frequently	1.56
29	Inter-departmental conflict is common	1.29	We have long production lead times	1.72	Produce much more than market demands	1.56	We have shortages of some sub-component at assembly points in the plant	1.38	We have to sell excess finished goods at reduced price	1.50
30	Too much work in process inventory	1.25	We have considerable amount of scrap/ high re-work	1.63	Production batch sizes are too large	1.25	Bottlenecks in our plant shift frequently	1.38	We have to split batches to rush product through for a customer order	1.50

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31	Parts common to several products end up in the products not currently in demand	1.13	We have shortages of some sub-component at assembly points in the plant	1.61	We have to sell excess finished goods at reduced price	1.22	We have to split batches to rush product through for a customer order	1.29	We have considerable amount of scrap/ high re-work	1.50
32	Production batch sizes are too large	1.13	Parts common to several products end up in the products not currently in demand	1.39	Parts common to several products end up in the products not currently in demand	1.22	Parts common to several products end up in the products not currently in demand	1.13	Too much work in process inventory	1.40
33	Others (company specific)	0.00	Production batch sizes are too large	1.33	Others (company specific)	0.00	Others (company specific)	0.00	Others (company specific)	0.00

Note: End of table.

Table E4: Concerns' Financial Impact by Average Score – Individual Plants.

Plant	A		V		T		I		Combination	
Rank	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver	Concerns	Aver
1	Forecasts are often not correct	2.14	Others (company specific)	3.00	Resource utilisations are perceived to be unsatisfactory	2.29	Labour efficiencies/ utilisation are too low	2.33	Forecasts are often not correct	2.38
2	We have trouble meeting production due dates	1.88	Too much finished goods inventory	2.21	We have trouble meeting customer orders on time	2.22	We have considerable amount of scrap/ high re-work	2.17	Too much finished goods inventory	2.10
3	We have trouble meeting customer orders on time	1.88	Too much raw materials inventory	2.17	There are walls of distrust between staff at various management levels	2.17	Forecasts are often not correct	2.14	We have trouble meeting production due dates	2.00
4	Produce much more than market demands	1.86	Inventory carrying costs are too high	2.16	Too much raw materials inventory	2.11	Too much raw materials inventory	2.00	We have trouble meeting customer orders on time	1.90
5	Too much finished goods inventory	1.75	Labour efficiencies/ utilisation are too low	2.00	Inventory carrying costs are too high	2.00	Inventory carrying costs are too high	1.83	Too much raw materials inventory	1.89
6	Inventory carrying costs are too high	1.75	Products do not get sold immediately	1.95	We have high documentation of activities	2.00	Resource utilisations are perceived to be unsatisfactory	1.83	Products do not get sold immediately	1.78
7	The plant experiences wave-like flow of work	1.75	We have too many setups	1.88	Labour efficiencies/ utilisation are too low	2.00	We have too many setups	1.83	The sales department expect unrealistic delivery times	1.75
8	Our estimated sales inflate demands on production	1.67	Forecasts are often not correct	1.84	The plant experiences wave-like flow of work	2.00	Process change over (setups) takes too long	1.83	We have shortages of some sub-component at assembly points in the plant	1.70
9	Too much raw materials inventory	1.63	We have considerable amount of scrap/ high re-work	1.83	Process change over (setups) takes too long	2.00	The plant experiences wave-like flow of work	1.75	We have long production lead times	1.70
10	We have shortages of some sub-component at assembly points in the plant	1.63	We have trouble meeting customer orders on time	1.79	We have trouble meeting production due dates	1.89	There are walls of distrust between staff at various management levels	1.75	Parts common to several products end up in the products not currently in demand	1.67
11	We have long production lead times	1.63	Produce much more than market demands	1.74	Unplanned overtime	1.89	Too much finished goods inventory	1.71	Labour efficiencies/ utilisation are too low	1.67
12	We have too many setups	1.63	We have to sell excess finished goods at reduced price	1.71	We have considerable amount of scrap/ high re-work	1.88	Produce much more than market demands	1.71	We have too many setups	1.67
13	Products do not get sold immediately	1.50	There is a lot expediting	1.71	Too much finished goods inventory	1.86	There is lack of staff able to perform cross functional tasks	1.71	Sales accuse production of being too slow to respond	1.63
14	We have to split batches to rush product through for a customer order	1.50	The plant experiences wave-like flow of work	1.71	Products do not get sold immediately	1.83	Production batch sizes are too large	1.67	We have to sell excess finished goods at reduced price	1.60
15	There is a "protect your rear parts" mentality among staff members	1.43	Unplanned overtime	1.68	We have to split batches to rush product through for a customer order	1.83	There is a "protect your rear parts" mentality among staff members	1.63	Unplanned overtime	1.60
16	We have to sell excess finished goods at reduced price	1.38	There is lack of staff able to perform cross functional tasks	1.68	There is a lot expediting	1.80	Products do not get sold immediately	1.57	Our estimated sales inflate demands on production	1.57
17	Resource utilisations are perceived to be unsatisfactory	1.38	Bottlenecks in our plant shift frequently	1.68	There is lack of staff able to perform cross functional tasks	1.78	We have trouble meeting production due dates	1.57	Produce much more than market demands	1.56
18	Inter-departmental conflict is common	1.33	Process change over (setups) takes too long	1.68	Bottlenecks in our plant shift frequently	1.75	We have trouble meeting customer orders on time	1.57	There is lack of staff able to perform cross functional tasks	1.56
19	There are walls of distrust between staff at various management levels	1.29	Too much work in process inventory	1.67	Produce much more than market demands	1.71	Inter-departmental conflict is common	1.50	Too much work in process inventory	1.50
20	The sales department expect unrealistic delivery times	1.29	Our estimated sales inflate demands on production	1.67	We have too many setups	1.71	Our estimated sales inflate demands on production	1.43	Inventory carrying costs are too high	1.50
21	Too much work in process inventory	1.25	We have trouble meeting production due dates	1.63	Forecasts are often not correct	1.67	Sales accuse production of being too slow to respond	1.43	There is a lot expediting	1.50

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22	Unplanned overtime	1.25	Resource utilisations are perceived to be unsatisfactory	1.63	We have long production lead times	1.63	We have to split batches to rush product through for a customer order	1.40	Resource utilisations are perceived to be unsatisfactory	1.50
23	We have high documentation of activities	1.25	There are walls of distrust between staff at various management levels	1.63	The sales department expect unrealistic delivery times	1.63	We have high documentation of activities	1.38	Production batch sizes are too large	1.50
24	There is lack of staff able to perform cross functional tasks	1.25	We have shortages of some sub-component at assembly points in the plant	1.59	Too much work in process inventory	1.57	We have long production lead times	1.33	Process change over (setups) takes too long	1.50
25	Process change over (setups) takes too long	1.25	We have long production lead times	1.59	We have shortages of some sub-component at assembly points in the plant	1.56	Bottlenecks in our plant shift frequently	1.33	We have considerable amount of scrap/ high re-work	1.44
26	Parts common to several products end up in the products not currently in demand	1.17	We have to split batches to rush product through for a customer order	1.59	Our estimated sales inflate demands on production	1.50	Too much work in process inventory	1.29	We have to split batches to rush product through for a customer order	1.33
27	Production batch sizes are too large	1.17	Sales accuse production of being too slow to respond	1.53	There is a "protect your rear parts" mentality among staff members	1.50	Unplanned overtime	1.29	Bottlenecks in our plant shift frequently	1.29
28	There is a lot expediting	1.14	The sales department expect unrealistic delivery times	1.47	Inter-departmental conflict is common	1.43	There is a lot expediting	1.29	The plant experiences wave-like flow of work	1.29
29	Labour efficiencies/ utilisation are too low	1.14	Inter-departmental conflict is common	1.37	We have to sell excess finished goods at reduced price	1.33	We have to sell excess finished goods at reduced price	1.20	There is a "protect your rear parts" mentality among staff members	1.29
30	We have considerable amount of scrap/ high re-work	1.13	Parts common to several products end up in the products not currently in demand	1.35	Production batch sizes are too large	1.20	We have shortages of some sub-component at assembly points in the plant	1.20	We have high documentation of activities	1.22
31	Bottlenecks in our plant shift frequently	1.13	Production batch sizes are too large	1.31	Sales accuse production of being too slow to respond	1.14	The sales department expect unrealistic delivery times	1.14	Inter-departmental conflict is common	1.14
32	Sales accuse production of being too slow to respond	1.00	We have high documentation of activities	1.26	Parts common to several products end up in the products not currently in demand	1.00	Parts common to several products end up in the products not currently in demand	1.00	There are walls of distrust between staff at various management levels	1.11
33	Others (company specific)	0.00	There is a "protect your rear parts" mentality among staff members	1.16	Others (company specific)	0.00	Others (company specific)	0.00	Others (company specific)	0.00

Note: End of table.

Table E5: Measures' Level of Importance – Overall Response.

Rank	Measures	Average	Count	Throughput/ Cost World
1	Others (company specific)	5.00	7	
2	Conformance to specifications	4.72	50	T
3	On-time delivery	4.63	48	T
4	Budget/Operating variances	4.17	47	C
5	Direct labour productivity	4.11	45	C
6	Dollars shipped per period	3.97	30	T
7	Cost reduction/ dollar savings	3.95	42	C
8	Response time	3.91	34	T
9	Conformance to production schedule	3.87	46	T
10	Machine efficiency	3.81	37	C
11	Downtime	3.76	42	C/T
12	Labour efficiency	3.76	41	C
13	Overhead cost	3.72	43	C
14	Labour utilisation	3.65	40	C
15	Cost per part	3.65	37	C
16	Production lead times	3.54	41	C/T
17	Inventory turnover	3.53	43	C/T
18	Rework cost	3.51	39	C/T
19	Standard hours produced	3.50	36	C
20	Scrap cost	3.49	41	C/T
21	Cost of quality	3.41	39	C/T
22	Overtime	3.33	39	C/T
23	Process setup times	3.13	38	C/T
24	Machine activation	3.10	29	C
25	Indirect labour productivity	3.00	32	C
26	Indirect labour efficiency	2.94	31	C
27	Downgrade cost	2.89	27	C
28	Process setup costs	2.82	33	C
29	Quality costs per unit of labour	2.70	27	C
30	Sales dollars per employee	2.67	30	C

Table E6: Overall Measures' Usefulness Rating – Overall Response.

Rank	Measures	Average	Count	Throughput/ CostWorld
1	Others (companyspecific)	4.86	7	
2	Conformance to production schedule	4.57	49	T
3	Process setup times	4.53	47	C/T
4	Process setup costs	4.13	46	C
5	Production lead times	3.93	44	C/T
6	Response time	3.93	41	C/T
7	Overhead cost	3.89	37	C
8	Scrap cost	3.88	40	C/T
9	Overtime	3.87	38	C/T
10	Downgrade cost	3.83	41	C
11	Machine activation	3.83	29	C
12	Labour efficiency	3.72	32	C
13	Rework cost	3.70	40	C/T
14	Standard hours produced	3.67	42	C
15	On-time delivery	3.65	37	T
16	Cost of quality	3.63	40	C/T
17	Direct labour productivity	3.59	34	C
18	Inventory turnover	3.50	42	C/T
18	Conformance to specifications	3.50	38	T
20	Cost per part	3.49	39	C
21	Cost reduction/ dollar savings	3.43	35	C
22	Indirect labour productivity	3.29	31	C
23	Indirect labour efficiency	3.20	30	C
24	Quality costs per unit of labour	3.13	24	C
25	Dollars shipped per period	3.11	37	T
26	Sales dollars per employee	3.07	28	C
27	Labour utilisation	2.82	34	C
28	Downtime	2.79	29	C/T
29	Budget/Operating variances	2.77	26	C
30	Machine efficiency	2.53	30	C

Table E7: Pearson Correlation between Measures' Level of Importance and Usefulness Rating.

Rank	Performance Measure	Pearson
1	Machine activation	0.89
2	Process setup costs	0.89
3	Conformance to production schedule	0.85
4	Standard hours produced	0.85
5	Rework cost	0.85
6	Downtime	0.84
7	Quality costs per unit of labour	0.84
8	Process setup times	0.80
9	Production lead times	0.80
10	Cost of quality	0.79
11	Overtime	0.78
12	Budget/Operating variances	0.78
13	Dollars shipped per period	0.78
14	Machine efficiency	0.75
15	Response time	0.75
16	Scrap cost	0.75
17	Direct labour productivity	0.75
18	Cost per part	0.74
19	Overhead cost	0.71
20	Sales dollars per employee	0.70
21	Downgrade cost	0.67
22	Labour utilisation	0.66
23	Cost reduction/ dollar savings	0.65
24	Inventory turnover	0.63
25	Indirect labour efficiency	0.62
26	Labour efficiency	0.59
27	Indirect labour productivity	0.59
28	Conformance to specifications	0.58
29	On-time delivery	0.55
30	Others, Please Specify:	-

Table E8: Concerns' Rate of Occurrence – Overall Response.

Rank	Concerns	Average	Count
1	Others (company specific)	3.00	1
2	Forecasts are often not correct	2.42	55
3	The plant experiences wave-like flow of work	2.04	53
4	Products do not get sold immediately	2.02	54
5	We have high documentation of activities	1.98	54
6	Too much raw materials inventory	1.94	54
7	We have too many setups	1.94	51
8	We have trouble meeting production due dates	1.93	56
9	Unplanned overtime	1.93	55
10	Inventory carrying costs are too high	1.93	54
11	Process change over (setups) takes too long	1.91	54
12	We have trouble meeting customer orders on time	1.89	56
12	There is lack of staff able to perform cross functional tasks	1.89	56
14	The sales department expect unrealistic delivery times	1.89	53
15	Sales accuse production of being too slow to respond	1.86	50
16	There is a lot expediting	1.85	47
17	We have long production lead times	1.85	53
18	Too much finished goods inventory	1.84	55
19	There are walls of distrust between staff at various management levels	1.81	54
20	Our estimated sales inflate demands on production	1.79	53
21	Labour efficiencies/ utilisation are too low	1.78	55
22	There is a "protect your rear parts" mentality among staff members	1.77	53
23	Resource utilisations are perceived to be unsatisfactory	1.76	54
23	Inter-departmental conflict is common	1.76	54
25	We have shortages of some sub-component at assembly points in the plant	1.74	53
26	We have to split batches to rush product through for a customer order	1.71	51
27	Produce much more than market demands	1.70	54
28	We have considerable amount of scrap/ high re-work	1.65	55
29	Bottlenecks in our plant shift frequently	1.64	53
30	Too much work in process inventory	1.60	53
31	We have to sell excess finished goods at reduced price	1.55	53
32	Production batch sizes are too large	1.35	51
33	Parts common to several products end up in the products not currently in demand	1.31	52

Table E9: Concerns' Financial Impact – Overall Response.

Rank	Concerns	Average	Count
1	Others (company specific)	3.00	1
2	Too much raw materials inventory	2.00	51
2	Too much finished goods inventory	2.00	51
4	Forecasts are often not correct	1.98	50
5	Inventory carrying costs are too high	1.90	50
6	We have trouble meeting customer orders on time	1.87	53
7	Labour efficiencies/ utilisation are too low	1.86	49
8	Products do not get sold immediately	1.78	49
9	We have trouble meeting production due dates	1.77	53
10	We have too many setups	1.77	43
11	Produce much more than market demands	1.71	49
11	The plant experiences wave-like flow of work	1.71	49
13	We have considerable amount of scrap/ high re-work	1.69	49
14	Resource utilisations are perceived to be unsatisfactory	1.69	48
15	Process change over (setups) takes too long	1.64	45
16	There is lack of staff able to perform cross functional tasks	1.62	52
17	We have long production lead times	1.59	49
18	Our estimated sales inflate demands on production	1.59	44
19	Unplanned overtime	1.58	53
20	We have shortages of some sub-component at assembly points in the plant	1.57	49
20	There are walls of distrust between staff at various management levels	1.57	49
22	We have to split batches to rush product through for a customer order	1.53	45
23	There is a lot expediting	1.52	44
24	We have to sell excess finished goods at reduced price	1.52	46
25	Too much work in process inventory	1.50	50
25	Bottlenecks in our plant shift frequently	1.50	48
27	The sales department expect unrealistic delivery times	1.47	49
28	Sales accuse production of being too slow to respond	1.40	47
29	Inter-departmental conflict is common	1.36	47
30	We have high documentation of activities	1.36	50
31	Production batch sizes are too large	1.36	39
32	There is a "protect your rear parts" mentality among staff members	1.34	47
33	Parts common to several products end up in the products not currently in demand	1.32	41

Table E10: Pearson Correlation between Concerns' Rate of Occurrence and Financial Impacts – Overall Response.

Rank	Company Concerns	Pearson
1	There is a lot expediting	0.69
2	We have too many setups	0.64
3	Process change over (setups) takes too long	0.61
4	Products do not get sold immediately	0.60
5	The plant experiences wave-like flow of work	0.60
6	Resource utilisations are perceived	0.54
7	Production batch sizes are too large	0.51
8	We have considerable amount of	0.51
9	We have to split batches to rush	0.51
10	There is lack of staff able to perform	0.50
11	Labour efficiencies/ utilisation are too low	0.48
12	Sales accuse production of being too slow to respond	0.44
13	Unplanned overtime	0.42
14	Inventory carrying costs are too high	0.42
15	Our estimated sales inflate demands on production	0.41
16	We have long production lead times	0.40
17	Too much raw materials inventory	0.40
18	The sales department expect unrealistic delivery times	0.39
19	Parts common to several products end up in the products not currently in demand	0.38
20	Forecasts are often not correct	0.38
21	Bottlenecks in our plant shift frequently	0.36
22	Too much finished goods inventory	0.35
23	We have trouble meeting production due dates	0.32
24	We have high documentation of activities	0.32
25	Inter-departmental conflict is common	0.31
26	There are walls of distrust between staff at various management levels	0.27
27	We have to sell excess finished goods at reduced price	0.26
28	Produce much more than market demands	0.24
29	There is a "protect your rear parts" mentality among staff members	0.24
30	Too much work in process inventory	0.11
31	We have trouble meeting customer orders on time	0.10
32	We have shortages of some sub-component at assembly points in the plant	0.04
33	Others (Company Specific)	-

Table E11: Survey Results' Return-on-Investment Classifications.

ROI Range	Count	%	Rank
Less than -20 %	1	2.33%	7
-20 to -15%	0	0.00%	14
-15 to -10%	1	2.33%	7
-10 to 5%	0	0.00%	14
-5 to 0%	1	2.33%	7
0.1 to 5%	4	9.30%	5
5.1 to 10%	6	13.95%	3
10.1 to 15%	9	20.93%	2
15.1 to 20%	10	23.26%	1
20.1 to 25%	5	11.63%	4
25.1 to 30%	1	2.33%	7
30.1 to 35%	2	4.65%	6
35.1 to 40%	0	0.00%	14
40.1 to 45%	0	0.00%	14
45.1 to 50%	0	0.00%	14
50.1 to 55%	0	0.00%	14
55.1 to 60%	0	0.00%	14
60.1 to 65%	0	0.00%	14
65.1 to 70%	0	0.00%	14
70.1 to 75%	0	0.00%	14
75.1 to 80%	1	2.33%	7
80.1 to 85%	0	0.00%	14
85.1 to 90%	0	0.00%	14
95.1 to 100%	0	0.00%	14
100.1 to 105%	0	0.00%	14
105.1 to 110%	0	0.00%	14
110.1 to 115%	1	2.33%	7
115.1 to 120%	0	0.00%	14
Greater than 120.1%	1	2.33%	7
Total	43	100%	

Table E12: ROI Classifications for Each Plant Type.

No.	ROI Range	Plant Type					Total
		A	V	T	I	Combo	
1	Less than -20 %	1	0	0	0	0	1
2	-20 to -15%	0	0	0	0	0	0
3	-15 to -10%	1	0	0	0	0	1
4	-10 to 5%	0	0	0	0	0	0
5	-5 to 0%	0	0	1	0	0	1
6	0.1 to 5%	0	2	1	0	1	4
7	5.1 to 10%	0	3	1	0	2	6
8	10.1 to 15%	1	3	2	1	2	9
9	15.1 to 20%	2	4	1	2	1	10
10	20.1 to 25%	1	2	0	1	1	5
11	25.1 to 30%	0	0	1	0	0	1
12	30.1 to 35%	0	0	2	0	0	2
13	35.1 to 40%	0	0	0	0	0	0
14	40.1 to 45%	0	0	0	0	0	0
15	45.1 to 50%	0	0	0	0	0	0
16	50.1 to 55%	0	0	0	0	0	0
17	55.1 to 60%	0	0	0	0	0	0
18	60.1 to 65%	0	0	0	0	0	0
19	65.1 to 70%	0	0	0	0	0	0
20	70.1 to 75%	0	0	0	0	0	0
21	75.1 to 80%	0	0	0	0	1	1
22	80.1 to 85%	0	0	0	0	0	0
23	85.1 to 90%	0	0	0	0	0	0
24	95.1 to 100%	0	0	0	0	0	0
25	100.1 to 105%	0	0	0	0	0	0
26	105.1 to 110%	0	0	0	0	0	0
27	110.1 to 115%	1	0	0	0	0	1
28	115.1 to 120%	0	0	0	0	0	0
29	Greater than 120.1%	0	0	0	1	0	1
	Total Response	7	14	9	5	8	43

Appendix F: Survey Responses to Q13

Plant Type	Questions: A. **How do you rate the current shopfloor performance measurement system in place? – Choose from 1 (lowest) to 5 (highest)[1].** B. **What is your reason(s) for choosing this scale?** Note: Key ideas have been underlined.
1. A	• Workflow varies month to month, difficult to measure performance against this background. We employ to cope with a mid-range workflow. Staff reluctant to work overtime can then require additional staff which can in slow periods impact efficiency. • Improves as new PBCS system upgrade gets underway. Excellent operation between departments and good understanding company wide of MRP II. • Low turn over of staff, good quality of machines and plenty of work. • <u>We currently are investigating ways to measure the performance of the shopfloor. Currently the system is very basic, but we are increasing the areas that are reported to be more comprehensive so we are able to define areas that need improving.</u> • <u>The system of quality control checks allows both graphical performance monitoring & fast feedback to operators & line supervision. Problem items requires written statement of problems & counter measure to be introduced to prevent repeat of problems.</u>
2. V	• Achieves our key objectives of IFOT and customer via expectations. • Performance based remuneration. • ISO 9001 Procedures, MRP II, Planned & regular meetings for various purposes & projects, e.g. production planning, environmental, health & safety, mgmt. review, etc. • The performance system was developed 20 years ago. It has evolved and further developed to meet company changing needs. • Ability to benchmark 4 regions between each other & internationally, KPIs in most areas. • We have a good tracking system and are really extending on KPIs. • They have achieved very good improvement last year, all working very hard. • Yet to be able to communicate Quality Policies & Strategic Plans to the manufacturing units effectively although some components are done well, i.e. BUQ Procedural Systems. • <u>We have statistical measurement of actual vs. guide for time, material and yield, as well as downtime. The objective measurements have surpassed subjective evaluations and individuals.</u> • <u>Delivery performance is not good enough and yet people do not fully understand its component in a value proposition.</u>

[1] Results to this part of question no. 13 are displayed in another section of the report.

	• Inadequate base data, communication sessions and staff training. • It is not yet skill based. It is not yet incentive based. • Low Work In Process (WIP), Quick Throughput Time, Multi-skilling. • Team work within shopfloor teams/crews (in & outside their own areas). Good communication between shopfloor and production management. • We have achieved world class operating performances in 2/4 plants by focusing squarely on high level operating measures for key activities (Recovery, Uptime, Rate). • Highlight areas of cost variance from standard to target improvement projects. • We are currently installing scheduling software to enable us to have real time information. This along with greater emphasis on KPIs and staff/plant utilisation is moving our focus towards "Customer Focus" with better control of the costs.
3. T	• ISO 9001 accredited, our systems are very good. • Measurement system has not been effective in changing attitudes at shopfloor level and therefore no improvement in performance has been achieved. • Hands on management - understand the process, relatively good production/sales interface: shared view that the customer is the common stakeholder, simple, shared KRAs at shopfloor level that focus on the things that matter generally, the process is measurable. Have just changed computer software. We are only now beginning to get good data standard vs. actual hours, and have only recently changed the product range, so some time will be needed for standards & benchmarks to settle down to a norm. • Good understand of business and its requirements. Teamwork is part of our way of doing things. • The performance measurement system does not show the people at the shopfloor level how their performance impacts on company performance.
4. I	• Good communication of meaningful KPIs keeps everybody involved. • Site runs a modified "Krone Technician Model" with a very flat support structure. The nature of the "shopfloor" work is such that intellectual capacity required is high, "Action Learning", etc. • Results of performance measurement not able to be used to enhance achievement of objective. • Poor level of shopfloor performance measurement currently in place. • Oliver Wight-Class A, Frequently achieving above target results. • Good, we would improve in systems for maintaining quality. Though, overall we are very consistent (customers tell us this). • Manufacturing conversion costs are small compared to the cost of raw & packaging materials. The shopfloor performance measures system focuses too much of labour productivity & machine efficiency & not enough on correct usage of raw & packaging material & the total cost of poor quality. • Our current systems are inadequate. We are about to put CAPRI

	manufacturing system into all our sites. The CAPRI programme has been tailored for our use. In the year 2000 a full SAP system will be installed throughout our company.
5. Combo	• Can be improved at a larger scale, measures in place now. • The company does not actively record & analyse some projected and actual measurements, e.g. m/c utilisation & set-up costs. Because of the size of the company there are only a few people who can perform these tasks. Company Schedule is on development for implementation. • Reasonable, a few basic measurement well understood at all levels. • Current measures are resulting in continuous improvement, although real gains in productivity are being driven by capital investment. • The company uses a variety of line processes & production measures (including management practices) in a standardised programme that allows us to compare/benchmark performance against similar organisation. This is assisted by participation in worldwide benchmarking studies e.g. Heineken & other competitors. • Targets our desired needs, delivery & quality, has proven itself to deliver on these over last 2 years. • Not enough about scrap per operation. No measure in place on CIP to measure change. Lack of communication to staff. • Process capability reviewed occurred last week. New targets set Workmanship < 200 ppm, Process < 5 ppm. We hope to achieve within 12 months. These are currently 2x higher.