UNIVERSITY OF NOTTINGHAM

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STRATEGIC MANUFACTURING EFFECTIVENESS: AN EMPIRICAL ANALYSIS

BY

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ABSTRACT

The difficulties that faced many manufacturing firms were attributed by Skinner (1969) to the inadequate attention given by top managers to the manufacturing function. He proposed a holistic framework of manufacturing strategy development that link manufacturing with corporate strategy. This work of Skinner is the first of three stages in the progression of thinking with respect to the strategic role of manufacturing as pointed out by Hum and Leow (1993). The other two stages being the demand of manufacturing to support and be consistent with corporate strategy (Wheelwright, 1978), and the present thinking that manufacturing can lead other functional areas in its contribution to the development of corporate strategy.

This research is concerned with the current understanding of the strategic role of manufacturing which was provided by Wheelwright and Hayes (1985). They suggested that even though strategic manufacturing effectiveness is developed along a continuum, there are four identifiable stages that can indicate a firm's position. Furthermore, they suggested that strategic manufacturing effectiveness can be operationalised through the emphasis that firms place on manufacturing choices and decisions; there are factors that affect strategic manufacturing effectiveness; and the higher the level of strategic manufacturing effectiveness, the better the firm's performance.

With respect to the factors affecting manufacturing effectiveness, Wheelwright and Hayes (1985) perceived five such dimensions. They are the attitude of top managers towards manufacturing, the involvement of manufacturing managers in setting the strategic direction of the firm, the emphasis on formulating manufacturing strategy, manufacturing proactiveness, and the co-ordination between manufacturing and other functions.

The framework of Wheelwright and Hayes (1985) is a diagnostic tool that is used to appraise manufacturing's role within a firm. However, the relationships among its constituents have not been examined in detail before. This research develops a model that clearly identifies such dimensions and how they influence manufacturing effectiveness. Also, the notion that there are four identifiable stages is investigated. Moreover, mediating effects of the types of industry, the sizes of firms, and the types of production process on manufacturing effectiveness are also examined.

The results from hypotheses testing indicated the significance of the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firm as being the key factors that influence the process of acquiring strategic manufacturing effectiveness.

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Chapter 1:

Introduction

1.1: Overview
1.2: The Four Stages Framework
1.3: Objectives of the Research
1.4: Research Methodology
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1.1: Overview

In their review of manufacturing strategy, Anderson et al (1989) noted that one of the main themes of underlying arguments in the literature is that manufacturing should be viewed from a strategic perspective and must have a role to play in setting the strategic direction of the firm.

The thinking with respect to the role of manufacturing has progressed in three stages (Hum and Leow, 1992). The first stage is the initial awakening by Skinner (1969) with the recognition that manufacturing is the missing link in corporate strategy. Skinner noted that many senior managers were delegating policy decisions to manufacturing personnel which could have strategic consequences on the competitiveness of the firm as a whole.

Skinner specifically noted that there are strategic implications for manufacturing decisions and therefore strategic manufacturing issues should be incorporated within corporate strategy; there are contrasting demands placed on the manufacturing functions; there are trade-offs in the design of manufacturing systems; and the manufacturing function had been traditionally dominated by technically oriented managers. To overcome these problems, Skinner proposed a holistic framework for manufacturing strategy development.

The second stage in the progression of the role of manufacturing is the demand of manufacturing to support and be consistent with the corporate strategy. It was proposed by Wheelwright (1978) who showed how manufacturing strategy can be linked to corporate strategy by using the framework he provided for that purpose.

1.2: The Four Stages Framework

The third stage is the contemporary thinking that manufacturing can lead other functional areas in its contribution to the development of the corporate strategy. It was provided by Wheelwright and Hayes (1985) who suggested that even though strategic manufacturing effectiveness is developed along a continuum, there are four identifiable stages that can show a firm's position. Furthermore, they suggested that strategic manufacturing effectiveness can be operationalised through the decisions that firms take to improve manufacturing; there are factors that affect strategic manufacturing effectiveness; and the level of stages is related to performance.

The significance of the framework of Wheelwright and Hayes (1985) is that it offers a diagnostic tool to appraise manufacturing's role within a firm. Hayes *et al.* (1988, p. 357) summed the advantages for such a tool as follows:

1. It establishes an agreed-upon base from which to launch a major program of change, making it possible to track progress and compare it against the goals set.
2. It also helps top managers understand the depth and pervasiveness of the changes required to move from a lower stage to a higher one.

3. In addition, it spotlights the areas needing the most dramatic improvements and provides information about the approaches that other companies have followed.

4. Finally, it begins to focus the organisation's attention on the potential value of converting a manufacturing organisation that is at best neutral in its contribution to corporate success, to one that can provide a strong competitive advantage.

With respect to the factors affecting strategic manufacturing effectiveness, Wheelwright and Hayes (1985) recognised five such factors. They are the attitude of top managers towards manufacturing; the involvement of manufacturing managers in setting the strategic direction of the firm; the emphasis on formulating manufacturing strategy; manufacturing proactiveness; and co-ordination between manufacturing and other functions.

In order to examine the performance consequences of manufacturing effectiveness, the concept of manufacturing competence is used. This concept was proposed by Cleveland *et al.* (1989) and extended separately by Kim and Arnold (1993) and Vickery et al (1993).

By building on the concepts and ideas addressed above, the conceptual model underpinning this research was developed, and the research hypotheses were derived.

The conceptual framework is built around three inter-related elements which outline that (1) manufacturing decisions and choices that a firm makes can be used to represent the level or stage of strategic manufacturing effectiveness, (2) there are antecedent factors that influence strategic manufacturing effectiveness, and (3) the consequence of higher degree in strategic manufacturing effectiveness is better manufacturing performance.

Next, the hypotheses underlying this research were derived. Six hypotheses were delineated which represent the relationships between the seven dimensions in the conceptual framework. Thereafter, two more hypotheses were added. They are concerned with the notion that there are four identifiable stages in strategic manufacturing effectiveness, and the mediating effects of the types of industry, the sizes of firms, and the types of production process on effectiveness.

1.3: Objectives of the Research

Many researchers in the field of manufacturing strategy have indicated that there is a lack of empirical research in the field. For example, Samson and Sohal (1993) noted that:

> 'Although numerous conceptual frameworks have been developed, many of which are prescriptively appealing, there has been a singular lack of rigorous research studies aimed towards testing and validating many new manufacturing management ideas. Dozens of articles have appeared ....but the controlled field studies have generally been lacking with respect to many key questions' (p. 227).

With respect to the focus of this study which is the strategic role of manufacturing, Ward *et al.* (1994) stated that

> 'despite the conceptual support for a strategic role for manufacturing, the topic has been relatively neglected in empirical research on manufacturing strategy' (p. 338).

Consequently, there are four objectives for this research. The first objective is to examine the structure of the Wheelwright and Hayes (1985) framework. In particular, the examination is focused on how to measure strategic manufacturing effectiveness and the factors that may affect it directly. The second objective is to provide empirical evidence to support the notion that there are four stages in manufacturing's strategic effectiveness. The third objective is to investigate and confirm the positive effects of strategic manufacturing effectiveness on manufacturing performance. The last objective is to investigate the mediating effects of types of industry, the sizes of firms, and the types of production process used on manufacturing effectiveness.

The significance of this research is that the framework of Wheelwright and Hayes (1985) 'is widely used to analyse the role of operations in strategy development for manufacturing firms' (Chase and Hayes, 1991). However, its use at the moment is limited as a checklist which compares the characteristics of stage two and four as demonstrated by Hayes *et al.* (1988).

Firms which use the framework to gauge their position can only do so by estimating where they fall along the continuum of strategic manufacturing effectiveness. The framework, therefore, as it stands now can be considered as a loose compilation of the characteristics of low stage versus high stage effectiveness. It does not show the relationships among the various dimensions that constitute strategic manufacturing effectiveness. Moreover, no study has yet to examine the interactions among these dimensions. Therefore, the intention of this research is to build on the existing literature by developing a model that clearly identifies such dimensions and how they influence manufacturing effectiveness. Such an effort attempts to extend and complement the earlier works of Wheelwright and Hayes (1985) and Hayes *et al.* (1988) among others.

By recognising these factors, it becomes both easier and more structured for managers to identify the current positions of their companies and the required changes so that they can progress to a higher stage. This can be achieved by using the existing checklist to estimate the current position and then looking for ways to upgrade the role of manufacturing by emphasising those factors that can affect strategic manufacturing effectiveness but which firms are not good at, or indeed lack.

1.4: Research Methodology

There is a need for a high degree of correspondence between the constructs underlying a theory and the method by which they are measured. This requirement is even more crucial for the field of manufacturing strategy because the importance of construct measurement has not been grasped by empirical researchers in the field. The evidence is that previous studies did not take measurement issues at the core of their investigations. In summary, three critical issues were identified which are related to construct measurement. They are the consistency of construct definition, using nominal and single item scales, and the significance of assessing validity.

Defining a construct concisely is a very important step for developing better measures for that construct. It makes studies with such constructs reproducible and verifiable, and so a cumulative body of literature can be built.

Most of the empirical studies in manufacturing strategy, fortunately, used interval and multi-item scales. Such scales have the capacity to show 'within-group' differences and can be used in many statistical analyses.

On the other hand, the majority of manufacturing strategy studies did not satisfy standard measurement criteria. The assessment of validity and reliability in the research process can help detect if there are random and systematic errors so that corrective measures can be taken.

The field of manufacturing strategy, in general, has progressed slowly due to the factors above, in addition to others such as the lack of empirical studies, the dearth of cohesive efforts towards theory building, and the failure to adopt ideas from the more developed disciplines. However, the small body of empirical studies in the field, with all its contributions during the last two decades, suffers from its lack of methodological rigour. So, in order to avoid this pitfall, this research followed a research methodology that was based on the widely used paradigm for the development of measurement instruments that was formulated by Churchill (1979). This adapted paradigm consists of six steps. They are (1) defining the domains of the dimensions, (2) generating items to measure the dimensions, (3) collecting data, (4) exploring the data, (5) purifying the measures, and (6) testing the hypotheses.

The survey methodology, based on questionnaires, was used because it is the best means for data collection where a limited amount of information is required from a large set of companies. Because of the low response rate usually associated with questionnaires, great care was taken in its design.

Names and addresses of firms were obtained from the FAME database, and the questionnaires were sent to manufacturing managers in three industrial sectors. Clear instructions were given on how to complete the questionnaires, and a pre-paid addressed envelope was included for the convenience of the potential respondents.

A pilot study was conducted, in two stages, to pretest the survey instrument. In the first stage, six manufacturing firms were visited and interviewed, and the views and comments of the manufacturing managers in these firms were solicited. The second stage of pilot study involved sending the questionnaire, after incorporating some changes from the first stage, to fifteen companies in the manufacturing sector.

The final version of the questionnaire was mailed to 1257 manufacturing firms in late November 1995. Another wave of questionnaires was sent, after five weeks of the initial mailing, to all the firms that had not yet sent back the questionnaire. After excluding returned questionnaires which were not completed, a response rate of 26.6 percent was achieved.

An important first step in data analysis is understanding the data through exploratory data analysis (Tukey, 1977). Three types of data exploration were carried out. The first type of data exploration was the examination for nonresponse bias. The comparisons between respondents and nonrespondents, and between early and late respondents indicate that there was no nonresponse bias. Thus the sample is a fair representation of the population. That means the results from the analysis of the sample can be generalised to the entire population under study.

The second type of data exploration was checking for multivariate outliers. These are cases with extreme values that can have negative outcome on the results inferred from hypotheses testing. The analysis indicated that there are no cases in the sample which can be considered as outliers.

The third type was sample description. From this analysis, it was concluded that most of the firms are either small or medium in size, and use batch processes. It was also found that there are large differences between the firms in the sample with respect to how profitable they are in the marketplace.

After satisfactory results were obtained from the exploratory data analysis phase, the focus was shifted to the step of purifying the measures of strategic manufacturing effectiveness framework.

The process of purifying the seven latent variables in the strategic manufacturing effectiveness framework involved the assessment of reliability, unidimensionality, discriminant validity, and convergent validity. The assessments were conducted using the structural equation modelling technique as implemented in LISREL and also the statistical programme, SPSS.

The two step approach of Anderson and Gerbing (1988) for developing and purifying measures was utilised. This approach calls for purifying the measures of each latent variable individually in step one, and then examining the full model in step two.

In testing the reliability and validity of the measures, comprehensive details of analyses were presented. That makes it easier for other researchers to scrutinise the method used or apply it in similar research settings.

Subsequently, the assessment was conducted for the full model which comprises both the measurement models of all latent variables and the structural models showing the relationships among the latent variables. The evidence from this examination suggests that the hypothesised full model fits the data quite adequately, considering that most of the measurement scales in this research are new.

The eight hypotheses were then tested. The results supported some of the hypotheses. In particular, it was found that among the five factors that were hypothesised to affect strategic manufacturing effectiveness, two factors emerged as the key factors that influence the process of acquiring strategic manufacturing effectiveness. They are the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firm.

As for the hypothesis which states that there are four identifiable stages in strategic manufacturing effectiveness as specified by Wheelwright and Hayes, the application of cluster analysis revealed that only two stages are apparent in the sample of study. These two stages correspond to stages two and three.

It was also found that types of industry, the sizes of firms, and the types of production process used have mediating effects on manufacturing effectiveness. The implications of this observation, as well as all other findings from hypotheses testing are discussed in chapter thirteen.

1.5: Structure of the Thesis

This thesis is organised into thirteen chapters. The first chapter is this introduction. The second chapter reviews the work of Skinner (1969) and Wheelwright (1978) with respect to linking manufacturing with corporate strategy. The third chapter focuses on the work of Wheelwright and Hayes (1985) that proposes the four stages framework. The fourth chapter reviews the frameworks of manufacturing competence. The fifth chapter presents the conceptual framework and research hypotheses. In chapter six, issues related to construct measurement in manufacturing strategy research are discussed. Chapter seven examines the research methodology used in this thesis. In chapter eight, the constructs are operationalised. Chapter nine outlines issues concerned with data collection method. In chapter ten, exploratory data analysis is conducted. Measures purification and assessment are carried out in chapter eleven. Chapter twelve is devoted to hypotheses testing. The results and conclusions of this study, as well as the limitations of the research and suggestions for future research, are presented in the last chapter.

Chapter 2:

Linking Manufacturing with Corporate Strategy

2.1: Overview

The competitive difficulties that faced many manufacturing industries were attributed by Professor Wickham Skinner to the inadequate attention given by top managers to the manufacturing function. In one of his earlier articles, Skinner (1966) blamed senior executives for not being appreciative of the changes surrounding manufacturing and thus not knowing of other methods of gaining competitive advantage through manufacturing. The emphasis at the time was on mass production and on competing on efficiency and cost. That resulted on production managers being under intense pressure from competitors, marketing demands, internal control systems that are outmoded, and the acceleration of advances in equipment and process technology. Business education, furthermore, was not addressing the needs of managers and hence there was a shortage of talents in manufacturing departments. Nevertheless, Skinner's much-cited article of 1969 [Manufacturing - Missing Link in Corporate Strategy] is credited by researchers as the starting point for the field of manufacturing strategy.

Hum and Leow (1992) noted that there are steps in the progression of thinking with respect to the strategic role of manufacturing. The first step is the initial awakening with the recognition that manufacturing is the missing link in corporate strategy (Skinner, 1969). The second step is the demand of manufacturing to support and be consistent with corporate strategy (Wheelwright, 1978). The last step is the contemporary thinking that manufacturing can lead other functional areas in its contribution to the development of the corporate strategy (Wheelwright and Hayes, 1985).

This chapter and the next two examine three specific issues that have bearing on this research. The present chapter assesses the work of Skinner (1969, 1974) and Wheelwright (1978) plus other studies which have had impact on our understanding of manufacturing strategy in the early years.

Afterwards, in chapter three, the main focus of this research is presented, i.e. the Wheelwright and Hayes (1985) framework of strategic manufacturing effectiveness. In that chapter, issues relating to the structure of this framework and other studies based on it are investigated.

The consequences of strategic manufacturing effectiveness can be argued to be better operational manufacturing performance. Thus, issues related to the measurement of manufacturing performance are discussed in chapter four.

2.2: Initial Awakening

Skinner noted that from the research he conducted in manufacturing firms, many senior managers were delegating policy decisions to manufacturing personnel. He stated that

> 'top management unknowingly delegates a surprisingly large portion of basic policy decisions to lower levels in the manufacturing area. Generally, this abdication of responsibility comes about more through a lack of concern than by intention. And it is partly the reason that many

> manufacturing policies and procedures developed at lower levels reflect assumptions about corporate strategy which are incorrect or misconstrued' (Skinner, 1969, pp. 136).

Such decisions could have strategic consequences on the competitiveness of the firm as a whole. This failure to recognise the relationship between corporate strategy and manufacturing decisions can put a firm in a non-competitive environment where it would be expensive and time consuming to amend the situation. This predicament, as Skinner suggested, is due to senior managers viewing manufacturing 'as requiring involved technical skills and a morass of petty daily decisions and details' (Skinner, 1969, p. 137). Thus they distance themselves from manufacturing. The outcome of this view of manufacturing was that it was perceived as a dead end for career aspirations where there were no chances for promotion, as Skinner (1969) noted:.

> 'manufacturing career is generally perceived as an all-consuming, technically oriented, hectic life that minimises one's chances of ever reaching the top and maximises the chances of being buried in a minutiae' (p. 137).

This negative view of manufacturing made it very difficult for manufacturing departments to recruit able managers who possessed general management expertise. Business schools were also to blame for the lack of talented manufacturing managers, because the emphasis at the time was on graduating industrial engineers and computer specialists who were not taught basic management skills.

All in all, Skinner's opinion was that

> 'manufacturing is generally perceived in the wrong way at the top, managed in the wrong way at the plant level, and taught in the wrong way in the business schools' (pp. 137).

Skinner, after exposing the factors that were contributing to the problems that manufacturing was facing, argued that change was needed in the management of manufacturing. Four major points can be discerned from his article:

- There are strategic implications for manufacturing decisions and therefore, strategic manufacturing issues should be incorporated within corporate strategy. Manufacturing managers should have broader skills beyond the day to day routines of running the operations. They must take decisions with a long term viewpoint. Also, top management have to consider the consequences of manufacturing decisions as affecting the whole company and thus they should be involved in such strategic choices.

- There are contrasting demands placed on manufacturing functions. These demands stem from the competitive environment surrounding a firm. In order for manufacturing to be a competitive weapon, these demands must first be identified and then defined into manufacturing terms. For example, if the demand on manufacturing is to provide goods which are available from stock at low cost, then production systems must be organised to fulfil these two demands (immediate availability, and lower cost). That is, competitive strategy is identified first and then accordingly a manufacturing task is defined. In this regard Skinner noted that there are other venues of competing besides efficiency and productivity. A firm can choose to compete on the basis of quality, flexibility, delivery or service. However, a firm cannot compete on all these dimensions. The corporate strategy should indicate on which dimensions to compete. This point was further clarified by Skinner through the concept of the focused factory (Skinner, 1974).

- There are trade-offs in the design of manufacturing systems. Skinner noted that both senior and manufacturing managers 'do not state their yardstick of success precisely', and the reason for that was not knowing that trade-offs exist. Thus alternatives should be recognised in every decision area. As an example, when it comes to plant size, a decision must be made whether one large plant is better or many smaller ones are desirable. Such decisions can only be made if 'the alternative selected is appropriate to the manufacturing task determined by the corporate strategy' (Skinner, pp, 140).

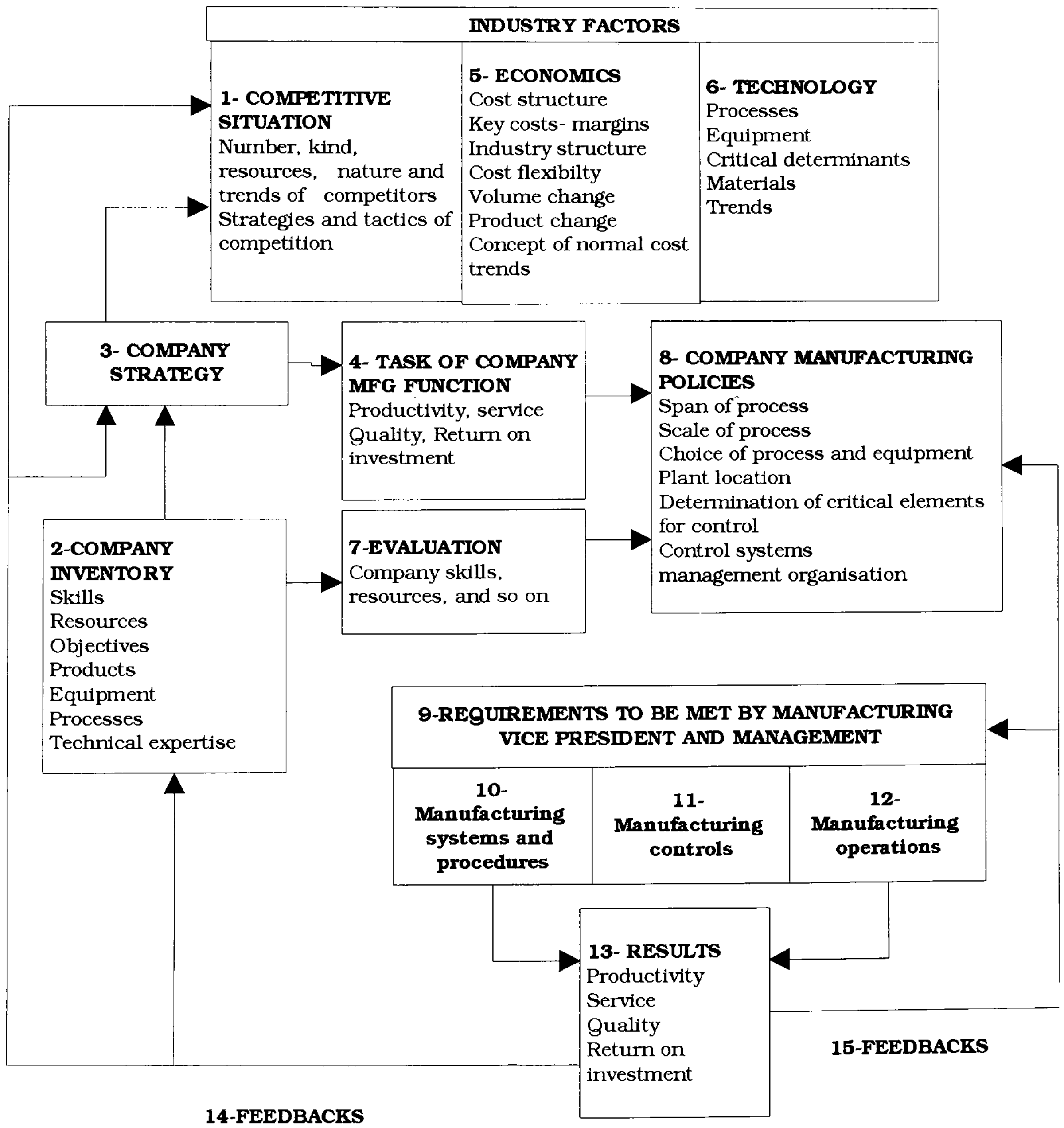
- The manufacturing function had been traditionally dominated by technically oriented managers who were trained in industrial engineering and computer science. This emphasis on technical expertise as Skinner (1969) noted

> 'produced an inward orientation toward cost that ignored the customer, and an engineering point of view that gloried in tools, equipment, and gadgets rather than in markets and service. Most important, the cult of industrial engineering

tended to make top executives technically disqualified from involvement in manufacturing decisions' (pp. 142).

In order to overcome the problems associated with manufacturing, Skinner proposed a holistic framework for manufacturing strategy development. This methodology which Skinner called 'manufacturing policy determination' is depicted in Figure 2.1.

Figure 2.1
Manufacturing Policy determination Process
Source: Skinner, 1969, pp. 143



Skinner (1969) suggested that there are fifteen steps in the process of manufacturing policy determination. For each step, Skinner provided a 'key' which clarifies the need for that step. These keys are shown in Table 2.1.

Table 2.1
Keys for the Process of Manufacturing Policy determination
Source: Skinner, 1969, pp. 143

1.	What the others are doing
2.	What we have got or can get to compete with
3.	How we can compete
4.	What we must accomplish in manufacturing in order to compete
5.	Economic constraints and opportunities common to the industries
6.	Constraints and opportunities common to the technology
7.	Our resources evaluated
8.	How we should set ourselves up to match resources, economics, and technology to meet the tasks required by our competitive strategy
9.	The implementation of our manufacturing policies
10.	Basic systems in manufacturing (e.g., production planning, use of inventories, use of standards, and wage systems
11.	Controls of cost, quality, flows, inventory, and time
12.	Selection of operations or ingredients critical to success (e.g., labour skills, equipment utilisation, and yields)
13.	How we are performing
14.	Changes in what we have got, effects on competitive situation, and review of strategy
15.	Analysis and review of manufacturing operations and policies

The significance of the ground-breaking ideas of Skinner is that they are in sharp contrast to the established old paradigm of Frederick Taylor and his followers who preached breaking down jobs in order to optimise each task individually, and then putting them back together. Even though he called it manufacturing policy, this work by Skinner is considered by many to be the start of the field of manufacturing strategy. Most of his original ideas have been the foundation of later studies in the field. However, some of these ideas are being challenged. One particular example is the concept of focus. Researchers (e.g., Nakane, 1986; Ferdows and De Meyer, 1990) have noticed that some companies have been able to do things better than their competitors on all fronts of production competence: they offer better quality and responsiveness to market demands, yet at lower costs. This competence defies the logic of the concept of focus, which assumes that a firm can not do everything better than its competitors, hence should focus its attention to one or two capabilities and make the necessary trade-offs. The literature is full of examples of manufacturers who are beating their competitors in all aspects of competence.

2.3: Reflecting Corporate Strategy in Manufacturing Decisions

The second step in the progression of thinking about the role of manufacturing in gaining a competitive advantage for a firm was presented by Wheelwright (1978). His work centred around two issues: (1) linking manufacturing strategy, as a functional strategy, to corporate strategy, and (2) providing a framework for manufacturing strategy development.

With respect to linking manufacturing strategy to corporate strategy, Wheelwright (1978) provided a framework, shown in Figure 2.2, that clarifies the interface between corporate strategy and manufacturing decisions. This linkage is through competitive priorities.

One of the important aspect of the work of Wheelwright (1978), as noted by Neely (1993), is that it is the first research to point to the fact that competitive priorities have multiple dimensions and can be measured in different ways as depicted in Table 2.2.

Figure 2.2
Manufacturing Strategy and Operating Decisions
Source: Wheelwright, 1978, pp. 62

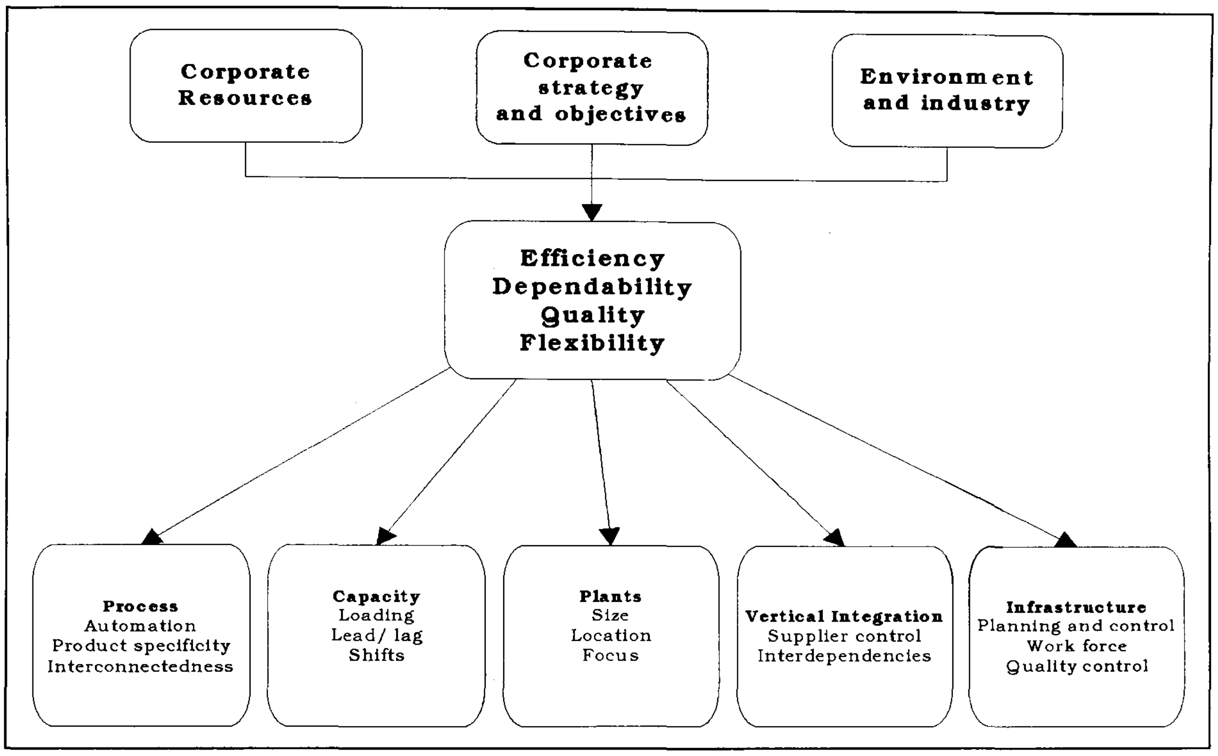


Table 2.2
Dimensions of Competitive Priorities and Ways of Their Measurement
Source: Wheelwright, 1978, pp. 61

Efficiency:
This criterion encompasses both cost efficiency and capital efficiency and can generally be measured by such factors as return on sales, inventory turnover and return on assets.

Dependability:
The dependability of a company's products and its delivery and price promises are often extremely difficult to measure. Many companies measure dependability in terms of percent of on-time deliveries.

Quality:
Product quality and reliability, service quality, speed of delivery, and maintenance quality are important aspects of this criterion. For many firms this is easy to measure by internal standards, but as with the other criteria, the key is how the market evaluates quality.

Flexibility:
The two major aspects of flexibility changes are in the product and the volume. Special measures are required for this criterion, since it is not generally measured.

Wheelwright (1978) also provided a framework for manufacturing strategy development. He was one of the first researchers to return to the holistic view of Skinner (1969) when he developed the conceptual framework depicted in Figure 2.3, which is an operationalisation of Skinner's framework of manufacturing strategy development.

Wheelwright (1978) justified this proposed framework by stating that

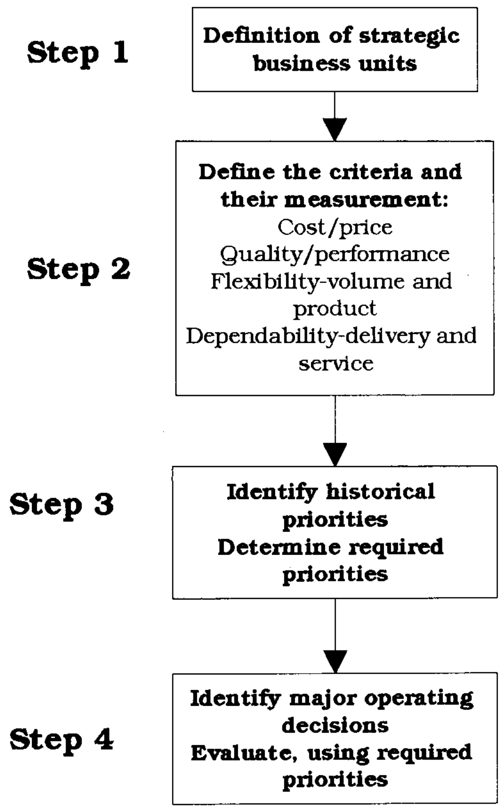
> 'Research and experience suggest that it is not enough just to communicate strategy throughout the organisation. Some intermediate mechanism is needed for translating strategy into a form directly applicable to manufacturing decisions' (pp. 57).

The steps of this framework are self-explanatory. However, it is worth noting that the focus of step 4 was mainly on facilities, process, capacity and vertical integration. This tendency to emphasise structural decision categories persisted during most of the 1980s until the significance of infrastructural decisions were noted by Hayes, Wheelwright and Clark in their book, "Dynamic Manufacturing" who stated that:

> 'we have seen a number of companies that were able to build a powerful competitive advantage around their internal capabilities and teamwork, even though their plants and equipment were not exceptional; but we have never seen one

that was able to build a sustainable competitive advantage around superior hardware alone. For this reason... it is almost impossible for a company to spend its way out of a competitive difficulty' (p. 22).

Figure 2.3
Manufacturing Strategy Development
Source: Wheelwright, 1978, pp. 63



The framework of Wheelwright (1978) has been utilised in much subsequent research (e.g., Buffa, 1984; Fine and Hax, 1984, 1985; Hayes and Wheelwright, 1984; Hayes, Wheelwright and Clark, 1988; Hill, 1989; Platts and Gregory, 1990).

2.4: Strategic Decisions in Manufacturing

As noted earlier, structural decisions have been emphasised much more than infrastructural decisions. Part of the reason is the inability of managers to differentiate between strategic and tactical decisions in manufacturing. Infrastructural decisions were considered tactical or operational in nature, but not strategic. Thus, they were not included in the strategy development process. So, in order to examine the types of structural and infrastructural choices in manufacturing, it is important to examine first the concept of strategy, its definition and characteristics.

The concept of strategy has its roots in the military domain. It is a Greek letter that means 'the art of the General' (Galbraith and Kazanjian, 1986). It was used in the business literature to indicate long term plans. Nevertheless, there is no single definition of strategy. Scholars have tended to define it according to 'dimensions such as view of business, degree of complexity, and planning horizon' (Imam, 1991). Many management scholars have offered definitions of strategy. For example, Chandler (1962) defined it as

> 'The determination of basic long-term goals of enterprise and the adoption of course of actions and the allocation of resources necessary to carry out these goals' (p. 13).

Other definitions were proposed by the likes of Ansoff (1965), Andrews (1971), Glueck (1976), Hofer and Schendel (1978). However, Mintzberg (1987) suggested that there is no single definition of strategy and it might not be helpful to rely on just one definition. He, thus, articulated five definitions:

- Strategy as a plan: In this interpretation, strategies have two important characteristics: 'they are made in advance of the actions to which they apply, and they are developed consciously and purposefully' (Mintzberg, 1987).

- Strategy as a ploy: In some circumstances, it becomes necessary for a company to outwit its competitors by, for example, discouraging them from building new plants through its announcement to expand its capacity. Here the strategy is not really to expand capacity but to obstruct competitors from doing so.
- Strategy as a pattern: a general plan or a specific ploy are intended strategies. Mintzberg pointed out that strategies can be realised also through the consistency of behaviour. The pattern of actions can indicate the presence of a strategy even though there could be no plan behind this pattern.
- Strategy as position: is a way of placing the firm in an 'environment', in such a way that 'strategy becomes the mediating force - or 'match' according to Hofer and Schendel (1978)- between the internal and the external context' (Mintzberg, 1987). An obvious example of this type of strategy is the usage of niche markets to position a firm away from fierce competition.
- Strategy as perspective: indicates the 'character' of the firm in similar fashion to the importance of personality to a person. It is how a firm sees the world, and builds an ideology around its view. For example, IBM has built its ideology on a strong marketing force, whereas HP treats engineering this way .

The implications of these multiple definitions of strategy as Mintzberg (1987) argued are that

> 'all strategies are abstractions which exist only in the minds of interested parties - those who pursue them, are influenced by that pursuit, or care to observe others doing so. It is important to remember that no one has ever seen a strategy or touched one; every strategy is an invention, a figment of someone's imagination, whether conceived of as intentions to regulate behaviour before it takes place or inferred as patterns to describe behaviour that has already occurred' (p. 16).

Whereas there is no consensus on the meaning of strategy, there is however some agreement on the levels of strategy. Hax and Majluf (1984) and Hammermesh (1986) noted that there are four levels of strategy. They are:

- Institutional strategy which is concerned with the development of the character and purpose of the organisation. It embodies the corporate mission. At this level, such questions are asked: who are we? where are we going? (Noori, 1990).
- Corporate strategy deals with the identification of the businesses that a firm will compete in, and how resources should be allocated.
- Business strategy deals with the development of plans for each strategic business unit (SBU). Such plans identify the goals and objectives of the business and the means to attain them.
- Functional strategy (like manufacturing strategy) deals with each function in the SBU. They implement the business strategy of the firm.

Wheelwright (1985) provided the important characteristics of strategy. These characteristics as depicted in Table 2.3 are useful in the process of differentiating between what constitutes a strategic action from a tactical one.

Table 2.3
The Characteristics of Strategy
Source: Wheelwright, 1984, p. 82

Time Horizon:
Generally, strategy is used to describe activities that involve a long-term time horizon, both with regard to the time it takes to accomplish such activities and the time it takes to observe their impact.
Impact:
Although the consequences of pursuing a given strategy will not be clear until considerable time has elapsed, the ultimate impact will be relatively greater than the impact of shorter-term tactics or operating activities.
Concentration of effort:
The concept of strategy usually implies concentrating one's activity, effort, or attention on a fairly narrow range or dimension of pursuits. Implicitly, focusing on certain activities means that one must reduce the effort in other directions.
Pattern of decisions:
Although some companies need to make only a few major decisions in order to implement an entire strategy, most strategies require a pattern of decisions across a variety of sub-areas. Certain types of decisions must be repeated over time, and a number of secondary or supporting decisions are needed to implement the strategy.
Pervasiveness:
An organisation's strategy embraces a wide breadth of resource allocation processes and day-to-day operations. In addition, the need for depth requires that all levels of an organisation act instinctively in ways that reinforce the strategy.

Many researchers have proposed a classification of the types of decisions in manufacturing. Some of the important ones are shown in Table 2.4. It can be seen from the table that there is some consensus on the important structural and infrastructural decisions categories.

Table 2.4
Manufacturing Decisions Categories
Source: Neely, 1993

	Structural Decisions	Infrastructural Decisions
Skinner (1969)	• Span of process • Scale of process • Choice of process and equipment • Plant location	• Determination of critical elements for control • Control systems • Management organisation
Wheelwright (1978)	• Process • Capacity • Plants • Vertical integration	• Infrastructure
Buffa (1984)	• Product and process technology • Capacity • Facilities • Suppliers	• Operating decisions • Work force and job design
Hayes and Wheelwright (1984)	• Technology • Capacity • Facilities • Vertical integration	• Production planning • Organisation • Work force • Quality
Hill (1985)	• Process • Process positioning • Manufacturing systems • Work structuring	• Organisation structure • Function support
Hayes *et al.* (1988)	• Technology • Capacity • Facilities • Vertical integration	• Production planning • Quality • Organisation • Work force • New product development • Performance measurement
Roth and Miller (1990)	• Material flow- JIT • Advanced process technology • Capacity upgrade • Restructuring	• Resource improvement • Quality programmes • Information and systems

2.5: Summary

The progression of thinking with respect to the strategic role of manufacturing went through three stages. The first one was the initial awakening with the recognition that manufacturing is the missing link in corporate strategy. The second is the demand of manufacturing to support and be consistent with the corporate strategy. And the third stage is the contemporary thinking that manufacturing can lead other functional areas in its contribution to the development of the corporate strategy. Skinner (1969), Wheelwright (1978), and Wheelwright and Hayes (1985) were responsible, respectively, for the development of these three stages.

The first stage is attributed to Skinner who noted that many senior managers were delegating policy decisions to manufacturing personnel which could have strategic consequences on the competitiveness of the firm as a whole. He specifically noted that (1) there are strategic implications for manufacturing decisions and therefore, strategic manufacturing issues should be incorporated within corporate strategy, (2) there are contrasting demands placed on the manufacturing functions, (3) there are trade-offs in the design of manufacturing systems, and (4) the manufacturing function had been traditionally dominated by technically oriented managers. To overcome these problems, Skinner proposed a holistic framework for manufacturing strategy development.

The second step in the progression of thinking about the role of manufacturing was presented by Wheelwright (1978) who linked manufacturing strategy to corporate strategy and provided another framework for manufacturing strategy development.

The last step in the progression of thinking about the strategic role of manufacturing was provided by Wheelwright and Hayes (1985) and is the focus of the next chapter.

Chapter 3:

Competing Through Manufacturing

3.1: Overview:

The progression of thinking with respect to the strategic role of manufacturing advanced in three phases. The first two phases were examined in the previous chapter. The third phase is the current thinking that manufacturing should be more proactive in leading other functions in its contribution towards a firm's competitive advantage. This phase is considered in this chapter.

3.2: Stages in Strategic Manufacturing Effectiveness

This current thinking about the strategic role of manufacturing was presented by Wheelwright and Hayes (1985) who suggested that even though strategic manufacturing effectiveness is developed along a continuum, there are four stages that are identifiable, which can reveal the firm's position and the required transformations in order to move it to the next stage or to keep it from sliding to a lower stage. At one extreme of the stages, production offers very little support to a firm's success, whereas at the other end it contributes significantly to the competitive advantage of the firm.

As shown in Table 3.1, stage one and two firms can be characterised as having reactive strategies. For stage one firms, manufacturing's negative potential is minimised and neutralised so that it does not hinder efficiency and cost effectiveness. Manufacturing managers have no role to play in the strategic management of manufacturing, hence experts are called in when there are strategic decisions to be made. Manufacturing performance is monitored through internal management control systems. The ultimate objective is to ensure that manufacturing is kept flexible and reactive.

Table 3.1
Stages in Strategic Manufacturing Effectiveness
Source: Wheelwright and Hayes, 1985, p. 100

Stage 1	**Minimise manufacturing's negative potential: 'internally neutral'**	Outside experts are called in to make decisions about strategic manufacturing issues Internal, detailed management control systems are the primary means for monitoring manufacturing performance Manufacturing is kept flexible and reactive
Stage 2	**Achieve parity with competitors: 'externally neutral'**	'Industry practice' is followed The planning horizon for manufacturing investment decisions is extended to incorporate a single-business cycle Capital investment is the primary means for catching up with competition or achieving a competitive edge
Stage 3	**Provide credible support to the business strategy: 'internally supportive'**	Manufacturing investments are screened for consistency with the business strategy A manufacturing strategy is formulated and pursued Longer-term manufacturing developments and trends are addressed systematically
Stage 4	**Pursue a manufacturing-base competitive advantage: 'externally supportive'**	Efforts are made to anticipate the potential of new manufacturing practices and technologies Manufacturing is involved 'up front' in major marketing and engineering decisions (and vice versa) Long-range programmes are pursued in order to acquire capabilities in advance of needs

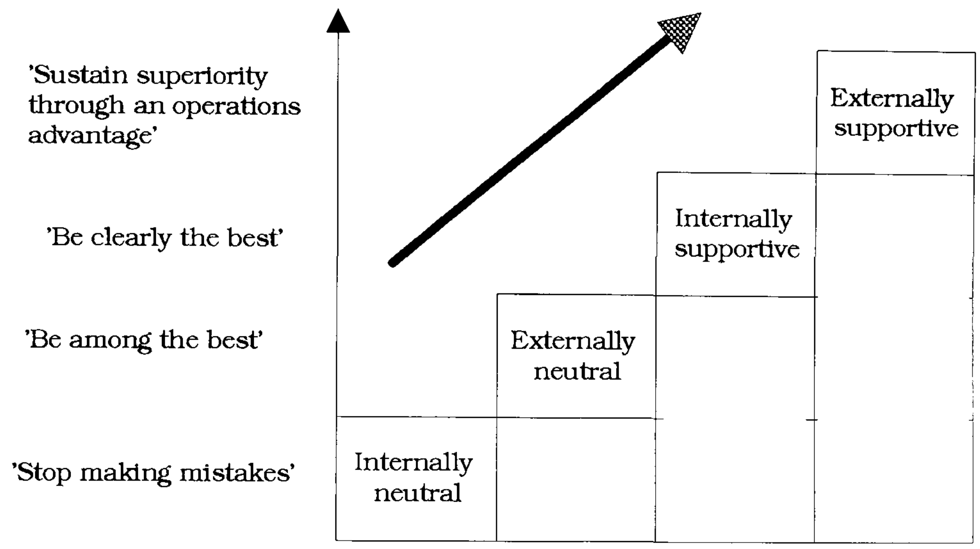
Stage two firms go beyond the steps taken by stage one firms and try to neutralise competitors for any competitive advantage they may have. This is done by following industry practices. The planning horizon for manufacturing decisions is extended to contain a single business cycle, and capital investment is seen as the principal method for achieving a competitive advantage.

As for stage three firms, the responsibilities placed on manufacturing are significant in comparison with the first two stages. Here, manufacturing has to provide support for the firm's competitive strategy. Investments in manufacturing are screened to make sure they are consistent with the objectives of the business strategy. Any changes in the business strategy are translated into manufacturing implications. Issues related to long-term manufacturing developments and trends are methodically addressed.

The fourth stage gives manufacturing a central role in the formulation and implementation of competitive strategies. Thus, manufacturing-based competitive advantage is sought. Efforts are made to predict the potential of new manufacturing practices and technologies. The involvement of manufacturing goes beyond its traditional domain to include the participation in major marketing and engineering decisions. In order to acquire capabilities in advance of needs, stage four firms pursue long-range programs.

Slack *et al.* (1995) viewed the framework of Wheelwright and Hayes from the perspective of the aspiration of the operations function. As shown in Figure 3.1, stage one firms try to stop making manufacturing-related mistakes. Stage two firms aspire to be among the best. Stage three firms are clearly the best in their respective industries. As for stage four firms, they sustain their clear-cut dominance over their rivals through an operations advantage.

Figure 3.1
Aspirations of the operations function
(the diagonal arrow shows the increasing contribution of operations)
source: Slack *et al.*, 1995, p. 52



Before reviewing the studies which are based on this framework, an attempt is made to resolve a potential misunderstanding. In particular, do the stages in Wheelwright and Hayes (1985) framework (internally neutral, externally neutral, internally supportive, externally supportive) refer to stages in the strategic role of manufacturing or do these stages refer to degrees of strategic manufacturing effectiveness? To rephrase this question with an example: if we denote a manufacturing function as internally supportive (stage three), does that mean the strategic role of manufacturing for that particular manufacturing function is to be internally supportive, or that the strategic role of manufacturing, regardless of its effectiveness, is to support, implement, and drive business strategy?

The confusion with what these stages denote stems from the fact that Wheelwright and Hayes (1985) used both 'the strategic role of manufacturing' and 'strategic manufacturing effectiveness' to describe the stages. For example, they labelled exhibit one on page 100 which summarises the characteristics of the stages as 'stages in manufacturing's strategic role', whereas before that, and on the same page, they used 'stages of manufacturing effectiveness' as the title of the section that contains the exhibit.

It is important to resolve this confusion since that will help in understanding the structure of this framework. In this regard, Slack *et al.* (1995) suggested that there are three roles for the operations function. These roles are:

Supporting business strategy: This role requires the operations function to develop resources and furnish capabilities that are required by the firm for it to fulfil its objectives.

Implementing business strategy: The role of operations is to put the business strategy into practice. The operationalisation of strategy by operations can be evident from its behaviour with respect to the objectives of a firm in gaining a competitive advantage over its rivals.

Driving business strategy: In this role, operations function gives a firm a long term competitive edge. The success of a firm is very much dependent on its operation's strengths.

An example of how these roles are executed in a firm is that of TNT, a firm which is engaged in world-wide freight mail and parcel transportation. These roles are shown in Table 3.2.

Table 3.2
The Roles of Operations in TNT
source: adapted from Slack *et al.* (1995), p. 49

Supporting business strategy
Operations must provide dependable delivery for all services with other performances objectives suitable for the nature of competition. Cost especially must be kept low in the heavy freight, and express post services. Quality of service is particularly important in the courier and Mailfast services. Speed of delivery is vital for the express post. The resources devoted to each of these services should be developed to emphasise the key aspects of competitiveness for each service.

Implementing business strategy
The group as a whole is moving towards being a fully comprehensive integrated supplier of its services world-wide. Operations must be able to evaluate alternative methods of achieving this and implement whatever investment in aircraft, vehicles, staff and systems is necessary.

Driving business strategy
Operations should move towards providing the capability to exceed competitors' performance and customers' expectations, initially in the more important aspects of competitiveness, and eventually in all aspects of performance. That means providing a more dependable, higher quality, faster, more flexible and cheaper service than any competitor.

It can be argued that the three roles which Slack *et al.* (1995) suggested are not distinct. There is a progression from one role to the next. For example, in order for operations to implement business strategy, it must have developed the resources and capabilities that would enable it to achieve that goal. That is, it must have in place the mechanism to support business strategy. Also for operations to drive business strategy, it must be able to support and implement it in the first place.

These three roles are analogous to the progression of thinking with respect to the role of operations that was described by Hum and Leow (1993) in the previous chapter. That means the role of operations at the current level of thinking is for it to drive business strategy, which Wheelwright and Hayes (1985) labelled as 'competing through manufacturing'. In doing so, it has to go through the process of learning how to support and implement the business strategy.

Thus, the strategic role of manufacturing in a firm, regardless of the status of manufacturing, is for it to drive business strategy. The four stages are measures of how effective manufacturing is. This is in accordance with the view of Slack *et al.* (1995) who observed that the four stages are used to

> 'evaluate the competitive role and contribution of the operations function of any type of company' (p. 50).

Thus strategic manufacturing effectiveness can be defined as:

the extent of support that the manufacturing function provides to the competitive advantage of a firm in its marketplace through its emphasis on choices and programmes that improve manufacturing.

After clarifying the distinction between the meanings of the strategic role of manufacturing and strategic manufacturing effectiveness, attention is now directed to the few studies which have attempted to utilise the framework of Wheelwright and Hayes.

The strategic manufacturing effectiveness framework formed the basis for two frameworks for service operations. The first one was conceptually developed by Chase and Hayes (1991) for classifying the stages of service firm competitiveness. The similarities to the stages of Wheelwright and Hayes (1985) are obvious, as they explained the characteristics of their framework as follows:

> In stage one, service firms are available for service. They tend to consider their operations organisations 'necessary evils.' In stage 2, companies agree not to compete against each other in terms of operations effectiveness. The firms all operate essentially the same way. They compete along other factors, such as breadth of product line or advertising. In stage 3, senior management has a clear vision of what creates value in the eyes of the customer and designs operations carefully to deliver that value. In stage 4, the company must develop the capabilities and credibility of its operations organisation to the point where operations becomes proactive and forces higher performance standards of the whole company (p. 15).

The other framework, which was empirically derived, was proposed by Roth and van der Velde (1991). They used the strategic operations choices and critical success factors that prevail in manufacturing strategy literature to operationalise their framework. By using a sample of 117 retail banks, they explored industry critical success factors along two dimensions: market-orientation and competitor-orientation. They showed that in order to make a service delivery system a potential marketing tool, the success factor criteria should be based on service task or mission.

Nevertheless, research efforts that have studied strategic manufacturing effectiveness from the standpoint of Wheelwright and Hayes framework are minimal. Most of the studies that referred to this framework employed it to indicate that a particular variable has implications on manufacturing effectiveness, or that a group of firms is in a specific stage. For example, Horte et al (1991), in their panel study of manufacturing strategies, characterised the strategic direction of companies in Sweden as defensive. Thus, these companies are probably in stage two where they follow their industry practices.

Hum and Leow (1992) assessed the perception of the strategic role of manufacturing by practising managers in Singapore. They used a measurement instrument that consisted of three factors. They are the role of manufacturing in corporate planning, the manufacturing task, and the strategic versus operational issues of manufacturing. They came to the conclusion that operations managers perceive that manufacturing can and should contribute to overall business strategy, and also operations managers demand that they should handle both strategic and operational decisions.

In their study of the role of manufacturing, Rafii and Miller (1994) identified communication of the firm's competitive strategy to its manufacturing function as a prerequisite for the integration of manufacturing into the corporate mainstream.

Ferdows and Lindberg (1987) suggested FMS as an indicator of the strategic role of manufacturing. They argued that the reason is that 'those who are emphasising FMS are also emphasising many of the other advanced ideas [for example, zero defects, JIT, CAD, CAM, quality circles] in the management of production'.

De Meyer and Ferdows (1990) studied the influence of manufacturing improvement programmes on performance and concluded that 'there are no simple cause-effect relationships between improvement programmes and manufacturing performance'.

Roth and Miller (1990) investigated the relationships between manufacturing and managerial success and business unit performance. They found in their study that managerial performance was associated with economic outcome when the size of business is controlled, and managerial performance is strongly associated with manufacturing performance.

The previous studies provide some anecdotal evidence for the characteristics of strategic manufacturing effectiveness, but none investigated the framework of Wheelwright and Hayes (1985) in any detail. Only the recent study by Hum and Leow (1996) made an attempt to examine the structure of this framework from both a theoretical and an empirical perspective. They used the comparison of the characteristics and practices of firms in stage two and four, that is provided by Hayes *et al.* (1988), as their vehicle for operationalising the Wheelwright and Hayes framework. As shown in Table 3.3, this comparison is built around the decision categories in manufacturing.

Table 3.3
Assessing a Manufacturing Organisation's Existing Pattern of Decisions
Source: Hayes *et al.* (1988)

Decision category	Stage 2	Stage 4
Capacity	Lags demand; capital-request driven	Matches or leads demand; capability driven
Facilities	General-purpose; static design	Focused; evolving design
Process technologies	Cost cutting; external sources	Capability enhancing; internal sources
Vertical integration/ vendors	Cost minimisation; seek leverage over	Provide capabilities; shared responsibility
Human resources	Reduce skills; source of energy	Develop competence; source of improvements
Quality	Acceptance levels; police role	Performance improvement; eliminate sources of errors
Production planning/ materials control	Centralised; detailed shop control; uncertainty accommodating	Decentralised; closely linked; uncertainty reducing
New product development	Sequential; over-the-wall handoffs	Parallel activities; interactive team
Performance measurements and reward	Detailed measurement of individual contribution	Focus on total organisation's performance
Organisation/ systems	Fragmented; staff co-ordinates	Integrated; line responsibility; staff supports

Hum and Leow (1996) then operationalised each decision category by items that capture the characteristics and practices in these categories as shown in Table 3.4.

Table 3.4
The Operationalisation of Strategic Manufacturing Effectiveness by Hum and Leow (1996)

Capacity
1. capacity vs. demand
2. extent to which capacity decision is made in response to demand
3. procedures used in evaluating capacity decision
4. capacity planning period/interval

Facilities
5. range of products that can be produced
6. degree of specialisation of equipment
7. average age of equipment

Process Technologies
8. source of information about new technologies
9. sources of new equipment
10. objectives for adoption of new technologies

Vertical Integration
11. objectives for vertical integration
12. relationships with suppliers
13. frequency in assisting suppliers in meeting company's objectives
14. number of suppliers

Workforce
15. extent to which workers help in improving production system
16. frequency of involving workers in decision making
17. scope of workers' job
18. level of skill required
19. frequency of job training

Quality
20. objective for establishment of quality control
21. function of quality measurement

Production Planning
22. degree of centralisation
23. management of uncertainty of demand forecasts

New Product Introduction
24. degree of interaction between the various departments

Performance Measurement
25. individual performance vs. organisational performance

Organisation
26. level of integration among departments
27. assistance among departments in developing plans and control systems

This work by Hum and Leow (1996) is important in the sense that it is the first effort which specifically attempts to operationalise the framework of Wheelwright and Hayes. However, it suffers from some limitations which are summarised below:

1. Hum and Leow (1996) did not differentiate between factors that affect (precede) and factors that directly measure manufacturing effectiveness. For example, with reference to Table 3.4, they used 'degree of interaction between the various departments' to measure 'new product introduction'. It is clear that such a measure represents a cause of new product introduction, whereas new product introduction can be measured by other means, such as the number of new products introduced in a year. Even though it is possible to use both cause indicator (indicator affected by a factor) and effect indicator (indicator affecting a factor), Hum and Leow (1996) did not differentiate between these two types. Failure to do so makes the interpretation of the results suspect (for an in-depth analysis of cause and effect indicators and the implications of using them, readers are referred to Bollen, 1989).
2. Most of the items in their operationalisation of strategic manufacturing effectiveness are considered manufacturing improvement programmes, however there are some items that measure manufacturing objectives (e.g., 'objectives for vertical integration'). Usually, companies state their objectives and then decide on the best improvement programmes that will lead to the realisation of these objectives. However, there are many ways to achieve an objective, depending on the circumstances of each

company. Thus, mixing improvement programmes with objectives can make the interpretation of decision category at best difficult and at worst unintelligible.

3. Their study was exploratory in nature, thus no hypotheses were proposed or tested. Moreover, they associated each decision category to the four stages subjectively depending on the percentage of respondents in each question. The strength of such associations without any formal statistical test is suspect. Also, the sample that Hum and Leow (1996) used, that consists of 55 respondents, is too small to infer any meaningful conclusions.
4. No reliability and validity assessments were conducted to the data gathered. The importance of conducting reliability and validity tests for empirical studies is discussed in chapter six.
5. Some scales they used in the questionnaire are questionable. For example, they used 'cost minimisation' as a scale descriptor at one end of a scale and 'strategic competitive advantage' on the other end. The construction of the Likert scale requires that it can measure an underlying concept continuously with the scale points conveying the continuity of the scale from one end to the other (Alreck and Settle, 1985). An example of a well-constructed scale is using 'strongly agree' and 'strongly disagree' as endpoints. So, with respect to the scale of Hum and Leow (1996), 'cost minimisation' cannot unambiguously be considered as the opposite of 'strategic competitive advantage'. Such a scale might confuse the potential respondents.

3.3: Assessment of the Four Stages Framework

Venkatraman (1989) noted that are there three approaches to strategy measurement:

1. Narrative approach: In this approach, strategy is described verbally in its holistic and contextual form. The view that is taken by its adopters is that strategy is 'an organisational process forever in motion' (Andrew, 1980). This approach, however, is not suitable for testing theories (Hempel, 1952).

2. Classificatory approach: This approach develops classifications of strategy conceptually and empirically. The conceptual classifications are termed 'typologies' (Hambrick, 1984). An example of that is Porter's (1980) generic business strategies. The empirical classifications are termed 'taxonomies'. The identification of three types of generic manufacturing strategies by Miller and Roth (1994) is an example of a taxonomy.

Venkatraman (1989) noted that while this approach

> 'serves to capture the comprehensiveness and integrative nature of strategy through its internal coherence, it does not reflect the 'within-group' differences along the underlying dimensions' (p. 943).

3. Comparative approach: This approach deals with the identification and measurement of key factors of the strategy construct. Therefore

> 'the focus is less on categorisation into one particular cell of the typology (or...taxonomy) but on measuring the differences along a set of characteristics that collectively

describe the strategy construct' (Venkatraman, 1989, p. 943-944).

The framework of Wheelwright and Hayes (1985) is classificatory and it was conceptually derived. Hence, it can be specified as a typology. Hambrick (1984) noted the following characteristics for typologies:

> 'Typologies represent a theorist's attempt to make sense out of non-quantified observation. They have the advantage of often being 'poetic' (Miles, 1983), that is, they ring true, often sounding very plausible. However since they are largely the product of rather personal insight, they may not accurately reflect reality. Or, more likely, they may serve well for descriptive purposes but have limited explanatory or predictive power' (p. 28).

Thus, there is scope to examine the framework of Wheelwright and Hayes (1985) through empirical validation. The basic factors for empirical assessment of this framework were recognised by Wheelwright and Hayes (1985). These are three inter-related elements which are presented below:

<u>The first element</u> of this model is that what contributes directly to strategic manufacturing effectiveness are the decisions and choices that a firm makes in order to improve manufacturing. This is clearly outlined by Wheelwright and Hayes (1985) when they indicated that

> 'Every manufacturing operation embodies a set of important choices about such factors as capacity, vertical integration, human resource policies, and the like...A given operation may be - and often is - composed of factors that are

> themselves at different levels of development. What determines the overall level of the operation is where the balance among these factors falls - that is, where in the developmental scheme the operation's centre of gravity rests' (p. 100).

For example, with respect to stage one, Wheelwright and Hayes (1985) noted firms in this stage

> 'typically view manufacturing capability as the direct result of a few structural decisions about capacity, facilities, technology, and vertical integration' (pp. 101).

Thus strategic manufacturing effectiveness can be operationalised through the emphasis that firms place on those choices and decisions that can improve manufacturing.

<u>The second element</u> of this model is that there are factors that moderate strategic manufacturing effectiveness. These factors through their existence or absence affect the level that manufacturing plays in supporting the competitive advantage of the firm. For example, Wheelwright and Hayes (1985) noted that there is a lack of communication between top managers and the manufacturing function in stage one firms. That is evident through the top managers' efforts to 'minimise their involvement with, and thus their perceived dependence on, manufacturing'.

<u>The third element</u> of this framework is that it is advantageous to be in higher stages. Wheelwright and Hayes (1985), even before articulating the stages in their framework, commented about the problems facing

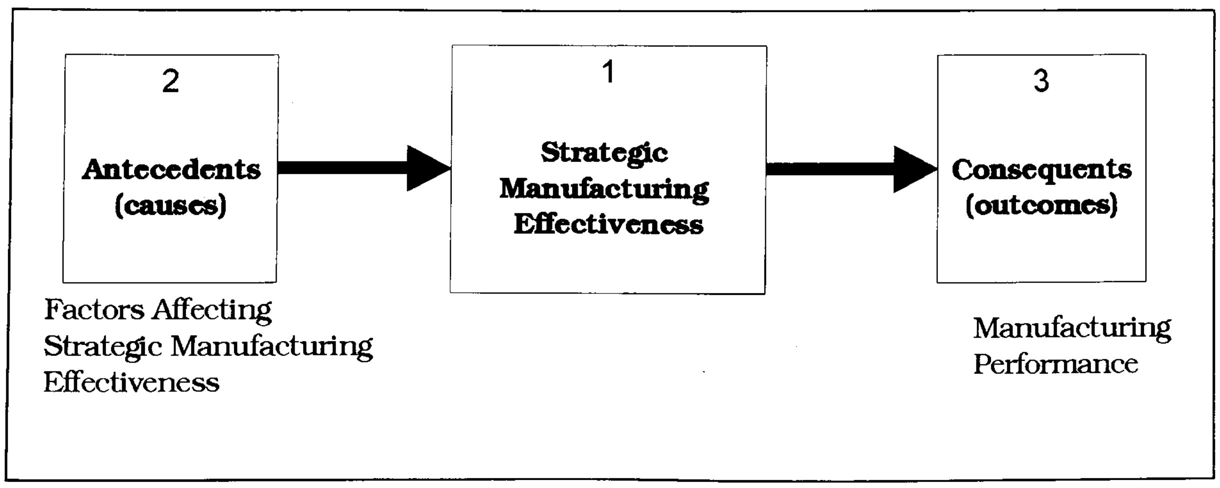
many American manufacturing companies because of intensified global competition by stating that:

> 'What makes this challenge so difficult is that the 'secret weapon' of their fiercest competitors is based not so much on better product design, marketing ingenuity, or financial strength as on something much harder to duplicate: superior overall manufacturing capability' (p. 99).

They implied that this superior overall manufacturing capability is the consequence of placing the manufacturing function in stage four where it will contribute substantially to the overall competitive advantage of the firm.

The three elements of this framework are depicted in Figure 3.2. They are explained in detail in the following order: first, the measures of strategic manufacturing effectiveness are reviewed in the following section. Thereafter, the factors affecting the role of manufacturing are examined. With respect to issues relating to manufacturing performance, they are discussed separately in the next chapter.

Figure 3.2
Antecedents and Consequents of Strategic Manufacturing Effectiveness



3.4: Strategic Manufacturing Effectiveness

Going back to the first element of this model, it indicates that decisions and choices that a firm makes in order to improve manufacturing contribute directly to strategic manufacturing effectiveness.

For manufacturing to be effective, it has to implement those improvement programmes that have been shown in both the academic and practitioner journals to have positive impact on manufacturing. As pointed out earlier in the previous chapter, researchers have categorised manufacturing decisions into specific categories as shown in Table 2.3. Each category encompasses specific manufacturing choices. The efforts to sort out these choices were led by researchers associated with the Manufacturing Futures Survey Project.

For example, DeMeyer and Ferdows (1990) presented a list of manufacturing improvement programmes, shown in Table 3.5. They used this list in the 1988 European Manufacturing Futures Survey questionnaire, and argued that even though:

> 'this list was of course not exhaustive. The fact that numbers grew from 36 to 39 [between 1986 and 1988], and that some of the programmes themselves were changed over the three years, is an indication that one can never describe the full set of feasible action programmes in manufacturing. Nevertheless, being the result of cumulative experience of an international team of production researchers in the US, Japan and Europe, the list is credible. Furthermore, the list has gone through recursive examinations of being presented

to a large number of executives and being modified over several years'. (pp. 121)

Table 3.5
List of Manufacturing Improvement Programmes
source: Ferdows and DeMeyer, (1990)

1. Giving workers a broad range of tasks	23. Narrowing product lines/ standardising
2. Giving workers more planning responsibility	24. Defining a manufacturing strategy
3. Changing labour management relationships	25. Integrating information systems between manufacturing and other functions
4. Manufacturing reorganisation	26. Integrating information systems within manufacturing
5. Worker safety	27. Vendor quality
6. Worker training	28. Reconditioning of physical plants
7. Management training	29. Just-in-Time
8. Supervisor training	30. Robots
9. Preventive maintenance	31. Flexible manufacturing systems
10. Zero defects	32. Closing plants
11. Manufacturing lead-time reduction	33. Statistical quality control (product)
12. Vendor lead-time reduction	34. Statistical quality control (process)
13. Computer-aided manufacturing	35. Improving new product introduction capability
14. Computer-aided design	36. Quality circles
15. Reducing set-up/changeover time	37. Automating jobs
16. Value analysis/product redesign	38. Production/inventory control systems
17. Group technology	39. Reducing the size of manufacturing work force (including hourly and salaried)
18. Capacity expansion	
19. Reducing size of manufacturing units	
20. Plant relocation	
21. Developing new processes for new products	
22. Developing new processes for old products	

The list of manufacturing improvement programmes, shown in Table 3.5, forms the basis for operationalising strategic manufacturing effectiveness, an issue that will be examined in chapter eight.

3.5: Factors Affecting Strategic Manufacturing Effectiveness

If manufacturing is to have a strategic role and be effective, certain factors must exist that act as enablers for it to achieve that goal. These factors are the antecedents of strategic manufacturing effectiveness. Wheelwright and Hayes (1985) did not make these factors explicit in any systematic way. However, they did point to them when they were describing the characteristics of the four stages. These factors are:

3.5.1: The Attitude of Top Managers Towards Manufacturing

This factor was expressed many times during the discussion of the four stages. For example, Wheelwright and Hayes (1985) suggested that for stage one firms, top managers 'try to minimise their involvement with, and thus their perceived dependence on, manufacturing'. A practical example that signifies the involvement of top managers is the empirical study carried out by Lefebvre and Lefebvre (1992) in 74 small manufacturing firms in the plastics industry. They found a positive relationship between the involvement and influence of chief executive officer (CEO) and the degree of process innovation.

Besides their attempt to minimise their involvement and dependence on manufacturing, Wheelwright and Hayes (1985) observed other negative aspects that are associated with the attitude of top managers towards manufacturing. For example, they consider manufacturing to be incapable of influencing competitive success. They encourage manufacturing to follow blindly industry practice in matters regarding the work force, equipment purchases, and capacity additions without understanding how manufacturing can provide competitive advantage. Their broad and uncritical views of manufacturing lead them to consider economies of scale related to the production rate as the most important source of manufacturing efficiency, and consequently they regard resource allocation decisions as the most effective means of addressing the major strategic issues in manufacturing. In summary, they think the best way of solving a manufacturing problem is to throw money at it and hope that everything will be all right.

Such negative and blurred view of the importance of manufacturing in gaining competitive advantage for a firm is usually associated with companies in stage one or two of the four stages framework. In higher stages, however, manufacturing is considered as a competitive weapon, and is treated as such.

In stage three and four firms, top managers communicate frequently with manufacturing managers to understand the problems facing them and how they can be solved. Such positive attitudes of top executives can have profound consequences on the way employees perceive their roles within a company. For example, the CEO of Apogee Enterprises Inc., a manufacturer of glass, windows and related products in the US persists on instilling pride in every employee at the company, and strives to set high performance expectations for them. In order to achieve that goal, he gives them the freedom and support to conduct their duties and he recognises and celebrates success. The managers of Apogee's 4 divisions are also empowered to make their own decisions. The CEO's objective is to make employees feel like owners of the company, not just workers (Brewer, 1995).

Another CEO of a major industrial supplier of aerospace systems and automotive parts commented that one of top management's significant roles is to 'coach people to win'. This role entails focusing on long term development of human resources. Such a commitment is bound to guarantee the provision of best-prepared employees to his company (Tichy and Charan, 1995).

3.5.2: Involvement of Manufacturing Managers in Setting the Strategic Direction of the Firm

Wheelwright and Hayes (1985) noted that one of the characteristics of stage three firms is that 'manufacturing managers take a broad view of their role by seeking to understand their company's business strategy and the kind of competitive advantage it is pursuing'.

In their study of the role of manufacturing, Rafii and Miller (1994) identified communication of the firm's competitive strategy to its manufacturing function as a prerequisite for the integration of manufacturing into the corporate mainstream. This communication can only be attained if the manufacturing managers are involved in strategy discussions with their superiors. Swamidass and Newell (1987), in an empirical study, used path analysis to conclude that the role of manufacturing managers in strategic decision making positively influences performance.

However, such a positive involvement of manufacturing managers is not apparent in lower stages. Hill (1993) observed that manufacturing managers view their roles as being only reactive to the demands placed on the production system. Whenever they have the chance to involve in corporate strategy debates, they do not explain manufacturing strategy issues effectively. Their involvement in corporate policy debates, anyhow, comes very late when the decisions have already been agreed upon, so they have little chance of changing the decisions that can affect manufacturing in a negative way.

This lack of confidence and involvement from the part of manufacturing managers is due, among other things, to their lack of education and training. Research studies (e.g., Oakland and Sohal, 1989; FaForge and Bittel, 1983) have indicated that the usual career path for manufacturing managers starts when they leave school at the age of 16 to begin manual work on the shopfloor. They progress to become managers without the needed exposure to the essentials of operations management.

Moreover, Hayes *et al.* (1988) found that part of the reason manufacturing managers are not involved in shaping corporate policies is that because they spend most of their time in dealing with routine operational matters. They just do not have adequate knowledge of how to view their roles from a strategic perspective. One method that can give manufacturing managers the opportunity to spend more time in strategic issues is through delegating some operational responsibilities to the shopfloor. This is what the director of facilities operations at G. D. Searle & Co. did. He spent the time which would usually be spent on day-to-day running of operations on bolstering the pharmaceutical company's bottom line through finding ways of saving time and money for the various functions in the firm. He managed to locate areas where there is scope for savings like the introduction of an in-house networked electronic printing facility, and the monitoring of the heating, ventilating, and air-conditioning system by technicians from their homes via lap-top computers. Such programmes would not have materialised if the director of facilities operations was concentrating his time on day-to-day operational matters (McMillan, 1994).

The importance of getting manufacturing managers involved upfront in business strategy is summed up by Samson and Sohal (1993) who noted that

> 'manufacturing managers must become more than just implementers of engineering and marketing instructions on the shopfloor. Raising the status of the manufacturing function involves getting the manufacturing manager involved in the business development/ market competitiveness debate. Manufacturing managers need to be interfaced with and have an understanding of the firm's customers' (p. 220).

3.5.3: Formulating Manufacturing Strategy

According to Wheelwright and Hayes (1985), this factor is absent in stage one and two firms, whereas stage three firms formulate

> 'manufacturing strategy complete with plant charters and mission statements to guide manufacturing activities over an extended period of time' (p. 102).

The importance and significance of developing manufacturing strategy is illustrated by Firestone New Zealand Ltd. When the tyres industry was deregulated, Firestone NZ found itself faced with increased competition from cheap imported tyres. To survive, the company had to re-establish its market leadership through competing effectively on both quality and price. Firestone NZ managed to survive and expand through the development of a 'strategy comprising a set of well co-ordinated objectives and action programmes aimed at securing a long-term sustainable advantage over competitors' (Paul and Suresh, 1991, p. 233). This example supports the empirical studies of Marucheck *et al.* (1990) and Tunalv (1992) who found that firms which have developed manufacturing strategies are substantially more successful than firms without one.

Researchers in the field have proposed many processes for manufacturing strategy development, some of which are quite detailed like the one proposed by Platts and Gregory (1990). Others are more general like that of Hill (1989) and Slack (1991). Hill's framework, composed of five steps, calls for identifying first corporate objectives and then translating these objectives to marketing strategy. The third step is deciding on how products win orders in the marketplace. This step identifies the needed manufacturing capabilities like cost, quality, flexibility, delivery. Next, in the fourth step, decisions are made with regards to process choices like alternative processes, capacity, process positioning, and for the last step, infrastructure issues are dealt with such as manufacturing planning and control, clerical procedures and organisational structure. The underlying theme of this framework is how the manufacturing function can support corporate objectives. The capabilities that manufacturing acquire should be compatible with the requirements of the marketplace.

Slack's framework, on the other hand, can be considered as an extension and explanation of Hill's framework, specifically with respect to the last three steps which are concerned with manufacturing objectives and structural and infrastructural decisions. The first step in Slack's framework is setting manufacturing objectives. After that, the achieved performance is judged and prioritised through the importance-performance gap. Then, action plans are developed accordingly.

In the case of firms which do not have a clear manufacturing strategy, they usually seek 'the help of outside experts to tackle strategic issues involving manufacturing' (Wheelwright and Hayes, 1985).

Strategy can be deliberately formulated or it can be emergent (Mintzberg, 1987). In either case, what is important is the consistency of decisions taken. This view is stressed by Hayes and Wheelwright (1984) who noted that

> 'It cannot be overemphasised that it is a pattern of decisions actually made, and the degree to which that pattern supports the business strategy, that constitutes a function's strategy, not what is said or written in annual reports or planning documents' (p. 30).

Similarly, Mintzberg and Waters (1982) argued that

> 'conceiving strategy in terms of intentions means restricting research to the study of the perceptions of what those who, it is believed, make strategy intend to. And that kind of research- of intentions devoid of behaviour- is simply not very interesting or productive' (p. 465).

Their argument is that if realised strategies are viewed as 'pattern in a stream of decisions', then strategies can be regarded as consistencies in the behaviour of firms. Consistency in decisions requires that each time a decision is considered it must be scrutinised before it is implemented. Wheelwright and Hayes (1985) noted that stage three firms screen 'decisions to be sure that they are consistent with the organisation's competitive strategy'.

The importance of screening decisions to make sure that they are consistent with corporate strategy is demonstrated by Cincinnati Milacron's Plastics Injection Machinery Business plant in Batavia, Ohio (Teresko, 1994). This plant developed a business strategy which called for reduced lead-times. The production department responded with redesigning its products into modules. That resulted in a production concept where products are manufactured in parallel instead of the old linear and sequential method of production. The outcome was a drastic reduction in lead-times.

The significance of screening decisions is emphasised by Wheelwright (1984) who observed that a competent manufacturing function is not ultimately one that assures the highest efficiency, or maximum productivity, but it is rather the one that aims for consistency between the requirements of the business strategy and its policies and capabilities.

Because developing thorough analysis is essential when confronted with a major decision to make sure it is consistent with the overall manufacturing strategy, there are many frameworks in the literature to facilitate analysing the pros and cons of a major decision. An example of such a decision support system is that of Roth *et al.* (1991). They presented a dynamic model that helps in examining strategic decisions with respect to the acquisition of flexible manufacturing systems (FMS). This model can indicate the benefits with respect to technological progress and economies of scope. It has such features as helping to identify relationships and trade-offs between external forces and decision variables; it shows the effect of FMS on the marketplace; and it reflects considerations regarding managerial risks and the time value of money.

Decisions concerning capital investments are probably the most important decisions that face manufacturing managers. How such decisions are considered and analysed is indicative of the way other decisions are contemplated. There are two approaches for considering capital investments decisions. The first one is the normative approach which emphasises financial considerations alone and does not view the strategic aspects of a potential project as significant (Pirttila and Sandstrom, 1995). This approach looks at capital investment from a purely profit maximising perspective. The other approach, called the process approach, integrates behavioural considerations into the capital budgeting process. The emphasis is both on the financial outcome of an investment and how it is going to contribute to manufacturing capabilities like quality and flexibility. Wheelwright and Hayes (1985) suggested that firms in higher stages incorporate nonfinancial considerations in their capital budgeting process.

Performance measurement and analysis of the outcomes of manufacturing decisions are important, just like the analysis of the appropriateness of these decisions before they are executed. Some manufacturing firms, however, employ very detailed measurements and controls of their operating performance. In this respect, Thackray

(1990) noted that one of the differences which distinguish Japanese manufacturing industries from their British counterpart is the absence of rigid control systems. Whereas British firms have a problem in that every improvement made has to be seen as a major step, the Japanese implement a continuous improvement philosophy through giving their people the scope and freedom to look for solutions themselves without the strictness of control systems impeding their efforts.

3.5.4: Proactiveness

Wheelwright and Hayes (1985) noted that one of the characteristics of stage three firms is that they are

> 'on the lookout for longer term developments and trends that may have a significant effect on manufacturing's ability to respond to the needs of other parts of the organisation' (p. 102).

They also suggested that stage four firms

> 'anticipate the potential of new manufacturing practices and technologies and seek to acquire expertise in them long before their implications are fully apparent' (p. 103).

Ward *et al.* (1994) investigated this factor and suggested that

> 'proactiveness is an important characteristic for identifying manufacturing functions that offer strategic benefit to the firm and those that do not' (p. 338).

They operationalised manufacturing proactiveness as being caused by manufacturing involvement and capability building programmes.

One important aspect of proactiveness is seeking new opportunities related to the present operations. These new opportunities can mean acquiring technology which can have a positive effect on competitive capabilities. It can also mean finding ways to increase market presence or maintain market leadership. With respect to acquiring technology, this can usually imply the complex task of locating an entirely new technology and introducing it into manufacturing. An important issue in this process is personal relationship. So in order to expedite this process, Deere & Co. initiated since 1990 a technology acquisition programme which it called 'People Who Know' for uncovering relevant technology or even finding that piece of information that can be useful in process improvement. During the past 5 years, the benefits from this programme for Deere & Co., which culminated in acquiring a variety of technologies, have significantly surpassed the cost of having to pay for staff associated with the programme (Boardman, 1995).

With regards to increasing or maintaining market leadership, Allen Bradley's Industrial Control Group division realised that the market for its products would increase by 1700% between 1988 and 1992. This was an opportunity for it to expand its present operations. Otherwise, if it was not ready, there was a chance that other suppliers would fill the gap. Allen Bradley toured many best-in-class electronics manufacturers to help it develop its strategic response to the market expansion. It then decided to build a new facility that has helped it fulfil its goals and at the same time reduce the time-to-market shipments of new equipment by 85% (Jasany, 1992). The contribution and significance of this CIM facility, which is called EMS1 (Electronic Manufacturing Strategy), is so enormous that it was described by a senior manager at Allen Bradley as 'not a facility, but a capability' (McKenna, 1992).

Proactiveness also involves taking some risks when making decisions. Risk taking is a virtue which can take place at any level of management as well as at the shopfloor. For example, Neff (1995) suggested that there are twelve important traits for today's CEO; one of them is 'good judgement anchored by prudent risk taking'. Story (1995) noted that part of the failure of empowerment programmes is due to management not encouraging employees to take risks.

If a firm wants to become a learning organisation, according to Kline and Saunders (1995), then it has to follow ten steps; among them is rewarding risk taking. The importance of risk taking for achieving a learning organisation is similarly advocated by a roundtable discussion of industry panellists who agreed that a climate of risk-taking is necessary if employees are to learn effectively (Chief Executive, 1995). Brown (1995) postulated that there are ten 'commandments' for managing firms toward the millennium, one of which is understanding the value of risk taking. Risk taking is also an important characteristic for teams (Temme, 1995). It increases in individual members their alertness and self-awareness (Supervisory Management, 1995).

One research study (Krueger and Dickson, 1994) found that managers who believe in themselves and consider themselves competent see more opportunities and take more risks. The reverse is true for non-competent managers. Motorola Inc., an American company, managed to thwart its Japanese competitors by its aggressiveness and risk taking approach. That emphasis is stated by Robert W. Galvin, chairman of Motorola who believes that the key to success lies in manufacturing firms' readiness to take major risks (Murray, 1989).

A proactive manufacturing function must also, as Wheelwright and Hayes (1985) indicated, forecast the potential of new practices and technologies and try to obtain them even before their significances are clear.

An example of firms anticipating the potential of new technology is Toshiba, the Japanese electronics goods manufacturer, whose managers 'target market opportunities and generate product specifications that draw initially upon emerging or even non-existent technology' (Herbert, 1989).

3.5.5: Co-ordination Between Manufacturing and Other Functions

This factor is more apparent in stage four firms where

> 'there are extensive formal and informal horizontal interactions between manufacturing and other functions that greatly facilitate such activities as product design, field service, and sales training'. (Wheelwright and Hayes, 1985, p. 103)

One aspect of co-ordination between manufacturing and other function is the interactive development of business, manufacturing, and other functional strategies. Such a co-ordination can become the difference between the survival and demise of a firm. Storage

Technology Corporation in Louisville, Colorado is a manufacturer of information storage and retrieval subsystems for high-end computer systems. It went into Chapter 11 [protection of bankrupt companies from creditors in the US during their attempt to restructure] in the mid 1980s. It then decided to form a cross-functional team to formulate cohesive corporate strategy. The team managed to get the involvement and commitment of top managers which consequently helped it to emerge from bankruptcy speedily (Stratton, 1991).

Another aspect of a co-ordinated effort between manufacturing and other functions is the continuous interaction among these functions to facilitate product design, field service, and sales training. 3M's life-sciences complex in St. Paul, Minnesota is an example of the interaction between manufacturing and other functions to help a firm in its product design. 3M produces over 60,000 various products from abrasives to image processing systems. Most of the companies it used to supply were deep in recession. However, being a leader in its markets, 3M recession strategy was to carry on doing what it does best, that is innovating and designing new products. To achieve that goal, it decided to form cross-functional teams from manufacturing and other departments which managed to clear the obstacles in the way of the flow of technology around the company and thus enhanced innovation and product design (Economist, 1991).

Co-ordination between manufacturing and other functions can also be set up for the purpose of transferring 'know-how' among the functions. However, transfer of know how can also happen within various manufacturing departments in large and diversified firms. For example, one of the duties of the corporate director of manufacturing systems in Motorola Inc. is to act as a matchmaker between various departments and groups that need a particular technology and others that can provide it (Horwitt, 1990).

Another example of within-function co-ordination is Bibby Sterilin Ltd., a British manufacturer of health care products which focused its manufacturing by five product groups. Each product group was assigned a team to develop a strategy relevant for its product portfolio. Afterwards, in order to promote communication and co-ordination, the teams were brought together to allow for cross-fertilisation of ideas among them. The co-ordination among the teams resulted in the agreement on common issues such as the necessity of product strategy to precede automation decisions and the need for consistency between short-term decisions and long-term plans (Bodnar and Harrison, 1991).

Also co-ordination can extend beyond a firm's boundary to include its suppliers. Wheelwright and Hayes (1985) noted that for stage one firms

> 'manufacturing operation can appear clumsy and unprepared when confronted with such straightforward tasks as .... helping suppliers solve problems' (p. 101).

Honda of America Manufacturing Inc. is an example of a firm which considers suppliers as strategic to the success of its business because 80% of the cost of a Honda automobile is purchased from outside suppliers. For that reason, Honda strives to develop its suppliers and make them adopt its systematic approach of reducing costs, increasing quality, and developing leading-edge technology (Fitzgerald, 1995).

3.6: Summary

The current understanding of the strategic role of manufacturing was provided by Wheelwright and Hayes (1985) who suggested that even though strategic manufacturing effectiveness is developed along a continuum, there are four identifiable stages that can show a firm's position. Furthermore, they suggested that (1) strategic manufacturing effectiveness can be operationalised through the emphasis that firms place on manufacturing choices and decisions, (2) there are factors that affect strategic manufacturing effectiveness, and (3) the level of stages is related to performance.

With respect to the factors affecting the role of manufacturing, Wheelwright and Hayes (1985) recognised five such factors. They are the attitude of top managers towards manufacturing, involvement of manufacturing managers in setting the strategic direction of the firm, the emphasis on formulating manufacturing strategy, proactiveness, and co-ordination between manufacturing and other functions.

Regarding the third element of Wheelwright and Hayes (1985) framework that there is a direct relationship between the level of stages and performance, this issue is the topic of the next chapter.

Chapter 4:

Manufacturing Competence

4.1: Overview

A firm that positions itself in stage four according to Wheelwright and Hayes' framework should perform better than a similar firm which is in a lower stage. Thus, strategic manufacturing effectiveness leads to better firm performance.

The performance outcome of strategic manufacturing effectiveness can possibly be examined at business or functional levels of an organisation. It can be examined at the business level through financial performance measures. Also, it can be explored at the marketing level through such measures as market share and market growth. However, since this research is investigating strategic effectiveness of the manufacturing function, the direct impact is expected to be at the manufacturing level, and thus manufacturing performance measures are considered. The other reason for considering only manufacturing performance measures is that financial and marketing performance measures are usually affected by the contribution of other functions. Consequently, it is difficult to isolate the contribution of manufacturing effectiveness on such measures.

Kim and Arnold (1993) noted that the field of manufacturing strategy does not have a well defined set of performance measures to test frameworks or theories, and to measure overall manufacturing capability. This predicament was recognised before by Nemetz (1990) who stated that:

> 'The manufacturing environment has changed in such a way that old performance measures are no longer meaningful.

performance.... Without publicly reported, standardised measures of performance, there is no straightforward method for conducting manufacturing research' (p. 64).

'he concept of 'manufacturing competence'[1] has been proposed in the iterature as a response to the absence of a viable measure of nanufacturing performance. Initially it was proposed by Cleveland *et ıl.* (1989), and then extended and refined by Vickery *et al.* (1993) and Kim and Arnold (1993). The three studies have shown that nanufacturing competence is a reliable measure of manufacturing performance, and it positively affects business performance. Consequently, they are reviewed and then compared.

.2: Framework of Cleveland *et al.* (1989)

Cleveland *et al.* (1989) depicted the concept of manufacturing ompetence as the linkage between business strategy and nanufacturing operations. They defined it as

> 'the preparedness, skill, or capability that enables manufacturers to prosecute a product-market specific business strategy' (p. 655).

'hey suggested that competence is a variable rather than a fixed ttribute and accordingly should be rated on a continuous scale. Their

Cleveland *et al.* (1989) and Vickery *et al.* (1993) called this concept 'production competence'. owever, I take the view of Kim and Arnold (1993) who argued that by using competitive riorities as the operationalising vehicle, the concept of production competence is broadened nd therefore it should be called manufacturing competence.

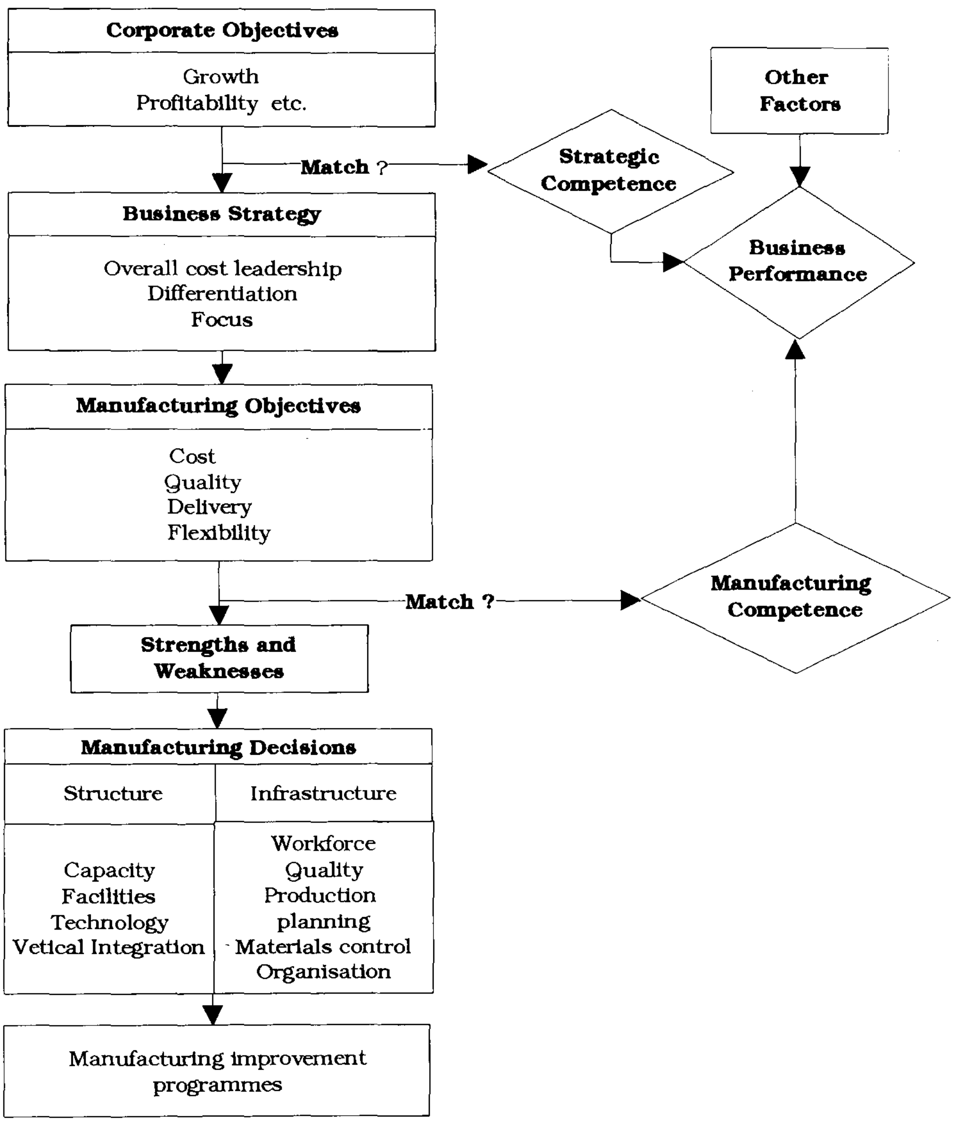
competence, and business performance. Porter's generic strategies of cost, differentiation and focus were used to form four distinctive strategies based on cost leadership and broad market focus, cost leadership and narrow market focus, differentiation and broad market focus, and differentiation and narrow market focus. Wheelwright and Hayes' product-process matrix was adopted to categorise production processes into job shop, batch, connect flow line, and continuous flow, and combined with the four strategies to form a process-strategy matrix. The relative strengths and weaknesses of a firm were identified in performance areas that form the dimensions of competence. Cleveland *et al.* identified the following nine performance areas: adaptive manufacturing, cost-effectiveness of labour, delivery performance, logistics, production economies of scale, process technology, quality performance, throughput and lead time, and vertical integration.

As for the business performance, it was measured using seven attributes. Four of these attributes represent manufacturing performance. They are cost, quality, dependability, and flexibility. Market share and growth rate represent marketing performance, and financial performance is measured by pre-tax return on assets.

Cleveland *et al.* used regression analysis and found that manufacturing competence is positively correlated with business performance.

nd Arnold (1993).

igure 4.1
im and Arnold's Framework of
lanufacturing Competence



Kim and Arnold (1993) used the notion of competitive priorities as the vehicle for operationalising the concept of manufacturing competence. They argued that:

1. 'The framework of competitive priorities has been one of the major building blocks in manufacturing strategy

2. 'The literature in manufacturing strategy has conceptualised this linkage between the business strategy and the manufacturing function with the framework of competitive priorities' (p. 5).

Kim and Arnold (1993) identified fifteen competitive capabilities which they classified into five categories of price, flexibility, quality, delivery and services as shown in Table 4.1.

Table 4.1
List of Competitive Capabilities
Source: Kim and Arnold (1993)

Price:
1. Manufacture with lower cost than competitors

Flexibility:
1. Make rapid design changes
2. Introduce new products quickly
3. Make rapid volume changes
4. Make rapid product mix changes
5. Offer broad line of products

Quality:
1. Manufacture with consistently low defect rates
2. Provide high performance products
3. Offer reliable products

Delivery:
1. Provide fast delivery of products
2. Deliver products on time as promised

Service:
1. Provide effective after- sales services
2. Provide product support effectively
3. Make products easily available (broad distribution)
4. Customise products to customer needs

ngth they possess in each of the fifteen capabilities. Afterwards, a nalised score was calculated to get relative measures by finding difference between a score and the overall average. They suggested this procedure was necessary in order to eliminate any inter-firm . Then, they developed a new construct called manufacturing petence index.

sets of competence indices were calculated. The first model ımed up the multiplication of normalised importance of petitive capabilities and normalised strength in those capabilities. second model is similar but used a weight variable in order to inate summing terms that have their normalised importance less ı one. This modification over the first model was introduced with argument that if a firm view a certain capability as unimportant, ı it does not matter if it is weak in that capability.

xploring the correlation between competence indices and the ness performance, and performing different statistical ysis, Kim and Arnold observed that:

ıe second model which included a weight variable is more presentative of the relationship between competence and erformance.

some industries, the concept of competence is not able to cplain the business performance.

nsiderably different.

Framework of Vickery *et al.* (1993)

ery, Droge and Markland (1993) introduced another framework of ufacturing competence. Compared with the framework of Kim and ld, it has a larger set of thirty one competitive capabilities. ery *et al.* measured the responsibility of manufacturing with ect to each capability and showed that, in some firms, tionally non-manufacturing activities like distribution can either under the sole control of manufacturing or be shared with other tions.

assessment of performance was carried out in three different ners: the performance of the firm relative to its competitors, the rmance of the firm relative to its historical performance for the eding fiscal year, and objective values for some financial measures obtained from a small number of firms.

statistical analysis of the data indicated that the best performance lted from a sound manufacturing competence coupled with a egy that is based on differentiation. The worst performance lted from a weak manufacturing competence combined with a egy that emphasises differentiation as its primary objective and as the second objective.

one is that of Cleveland *et al.* (1989). This framework had some comings which are summarised as follows (Vickery 1991, Vickery 1993):

small set of nine performance areas was chosen. These rformance areas combine elements of manufacturing tasks and anufacturing choices. Researchers (e.g., Tunalv 1992, Miller and th 1994) have differentiated between these two levels of anufacturing strategy as follows: manufacturing tasks are ncerned with the capabilities that a firm should have in order to mpete, and manufacturing decisions specify the structural and frastructural choices that are taken to build the required pabilities.

ie three point scale that Cleveland *et al.* used is limited. It does t have enough range to distinguish the degrees of strengths and aknesses.

ly six companies constituted the sample.

ie measure of business performance captures some of the same ms that are used to construct the manufacturing competence asure. This overlap explains to some degree the high positive rrelation, which is close to one between competence and rformance.

ther two frameworks of Kim and Arnold, and Vickery *et al.* differ following points:

anufacturing can share responsibilities for other competitive iorities that are not traditionally associated with manufacturing. ıey concluded their argument by stating that not only a more mprehensive set of competitive capabilities is required, but also ch one must be assessed if manufacturing is partially or wholly sponsible for it. However, their data showed that of the thirty one mpetitive priorities that they included in their study, around 'enty six have only a 50 % responsibility of the manufacturing nction. What is more, some of the competitive priorities are nilar. For example, they used these three competitive priorities: w production cost', 'competitive pricing' and 'low price' as stinctive priorities, even though only the first one can be argued be the responsibility of the manufacturing function.

m and Arnold did not explicitly relate their manufacturing mpetence model to the types of generic business strategies. They gued that the competitive priorities of the manufacturing nction capture the goals of business strategy by saying that:

By examining its competitive environment, a firm develops its business strategy. Then the goals of business strategy are ranslated into competitive priorities, and the firm's nanufacturing function deploys action plans to improve necessary strengths. The importance assigned to each of the competitive capabilities and the degree of strength achieved legree of this fit is captured as manufacturing competence' p. 7).

: two points indicate that the framework of Kim and Arnold ;) is better conceptually than the framework of Vickery *et al.* ;). This assertion is supported by the fact that Kim and Arnold the award for the best paper published in the International ıal of Operations and Production Management in 1993.

Summary

der to examine the performance consequences of manufacturing iveness, it is argued that such performance can be represented he concept of manufacturing competence. This concept is ined through the research of Cleveland *et al.* (1989), Kim and d (1993) and Vickery et al (1993). After comparing these studies, concluded that the study of Kim and Arnold (1993) is the most ical of the three.

ıg reviewed relevant literature on the concept of manufacturing etence, the next step is to build on the concepts and ideas that been examined in the last three chapters by developing a ;ptual model and research hypotheses. This task is the focus of ıllowing chapter.

ıceptual Framework
l Research Hypotheses

rlies this research and reflects the substantive hypotheses of ɜst. A conceptual framework is a theoretical model that attempts :plain real-world phenomena by expressed relationships among ɜpts (Blalock, 1969). The concepts are in themselves not ·vable but are latent in the phenomenon under study (Straub,). So, before addressing the objectives of this chapter, two etical considerations which have implications on the framework the hypotheses are first discussed. These are the use of servable variables in this research, and the utilisation of causal sis to represent relationships between constructs.

Jnobservable Variables

ature and applicability of unobservable [or latent] variables have scrutinised in many disciplines, but none more so than in the :ure of the philosophy of science which has witnessed fierce ɜs concerned with this issue (Boyd, 1991). Most of these debates ɜtween two schools of thought; the logical positivists and the :s. The logical positivists contend that one can never be certain existence of unobservables. Thus, according to this school of ht,

> heories that contain unobservables should not be judged n the basis of their correspondence to reality, but instead n their instrumental value as tools for generating

ɔpposing school of thought, represented by the realists, argues knowledge gained from scientific endeavours can point to the ɜnce of unobservable entities. The argument used by the realists ιt

when a theory that contains unobservable entities is well ɔorroborated by scientific evidence, then we may have good ɾeason for believing that those unobservable entities have a ɔorrespondence in reality. Thus...we can make statements ιbout the truth value of theories that contain unobservables' Godfrey and Hill, 1995, p. 520).

: debates between the logical positivists and the realists have icant implications for strategy research because most of the ies that are addressed in strategic management contain ructs that are unobservables.

ɔgical positivists have been attacked because of their inability to n such theories as quantum physics which are based on ɜervable entities. Thus the views of the realist position is adopted ɜ research, because this school of thought argues, according to ɜy and Hill (1995), that

ɜince our theories can give us knowledge about nobservables, it is legitimate to derive normative rules from ɿose theories that can be used to guide managerial action' ›. 520).

ɩecond theoretical consideration, which is an extension of the first is the assumption of causal relationships in models involving servable variables. Causality has been debated in many ɔlines. However, there is no consensus on its meaning and :e. Bollen (1989) argues that there are three components or .tions for causality. They are isolation, association, and the :ion of influence.

· example, there is a cause and effect relationship between two ɔles such that x is a cause and y is an effect, then isolation .s all the effects on y are due to x alone. That implies y is totally ed from being affected by other variables. Association between ariables like x and y means that they covary and correlate with nother. The last condition for causality is knowing the direction .uence. That is x influences y and not vice versa.

t these three conditions for causality, namely isolation, iation, and direction of influence, Bollen (1989) noted that

> Each condition is difficult to meet, but it is perhaps mpossible to be certain that a cause and an effect are solated from all other influences. We must regard all models .s approximations to reality' (p. 79).

roblems introduced by using latent constructs in a theoretical rk, by implying causality, does not stop with what has already pointed out. The critical issue is that whatever statistical

Because the non-observational hypotheses of a theory are ıot restricted to particular space or time locations, the ıumber of times a particular effect could be observed is ›otentially infinite. As a result, no matter how many positive ›bservations are obtained in support of a theory, the :ertainty of the theory is still in doubt' (p. 467).

ıs why the only way to accept a theory tentatively is to subject it ›rous tests repeatedly until it has accumulated enough evidence ; support or it is superseded by better theories. The need for a ıon, in manufacturing strategy, of building theories in a lative basis is an issue which is addressed in chapter seven.

rief discussion about latent variables and causal relationships he arguments presented above for using them are utilised to ·uct the conceptual framework, as outlined in the next section. conceptual framework, consequently, contains unobservable les in causal relationships.

onceptual Framework

mensions, or unobservable variables, of a strategy construct can ıved in two ways (Venkatraman, 1989):

specifying the dimensions *a priori*, that is developing the ›nsions beforehand based on the conceptual perspective of the ›truct definition. This pre-specification of the dimensions is then lated statistically using data analytic methods.

ılysis. This approach is recommended when there is little or no ːoretical foundation for *a priori* specification. However, it has two in limitations as Venkatraman (1989) pointed out. The first one that the dimensions derived may be meaningless and thus dies based on this method may not be repeatable. The second itation is that the method of data analysis used like exploratory tor analysis may take the central role in the development of the del.

ι *priori* method is utilised in this research because, as indicated apter three, Wheelwright and Hayes (1985) recognised three related elements in their framework, and the dimensions that itute these elements. The three elements are:

ıt contributes directly to strategic manufacturing effectiveness the decisions and choices that a firm makes to improve its nufacturing.

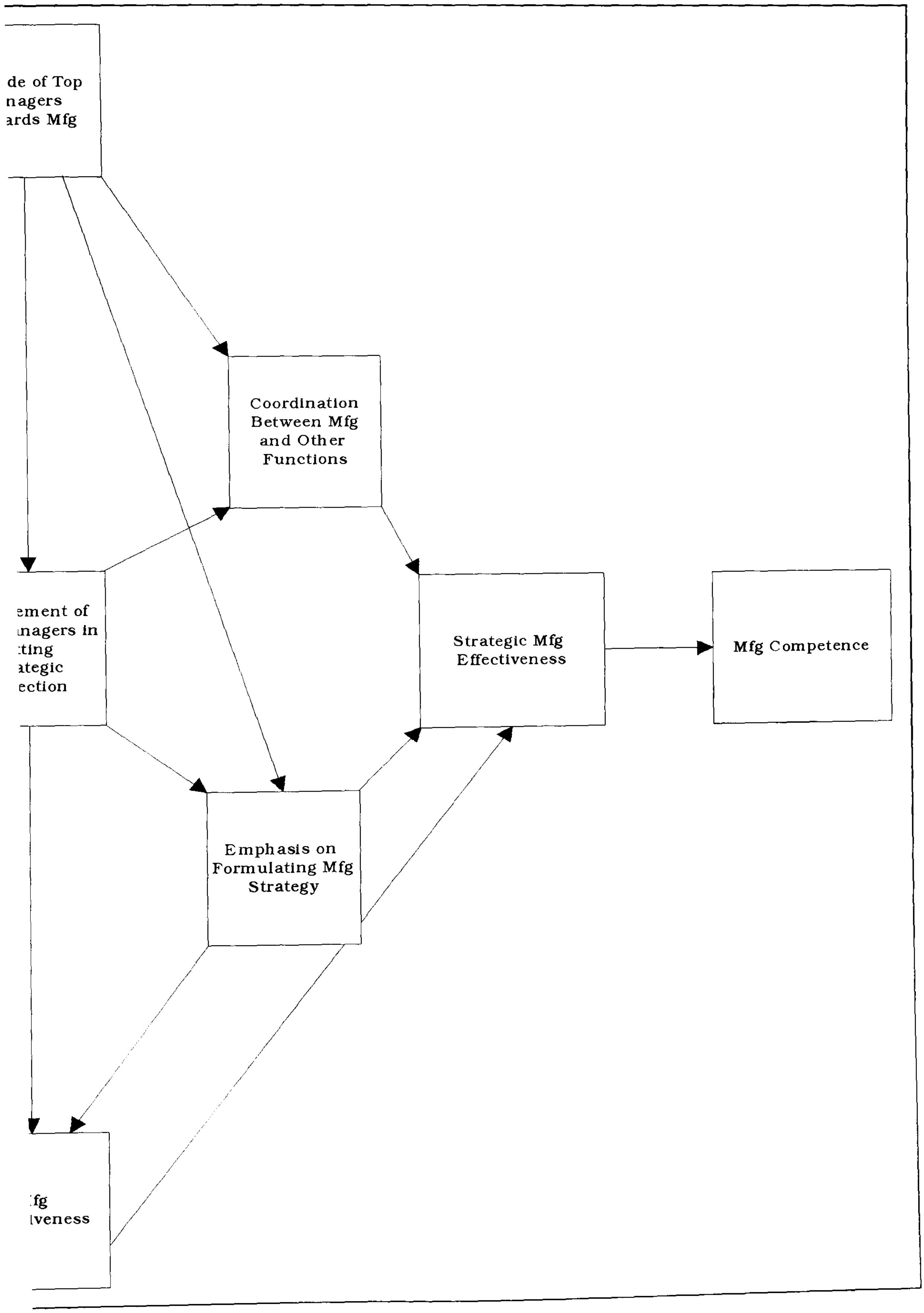
re are factors that influence strategic manufacturing ctiveness. These factors through their existence or absence ct the level that manufacturing plays in supporting the ıpetitive advantage of the firm.

s profitable to be in higher stages; meaning that there is a ·elation between the level of a stage and performance.

three elements, depicted in Figure 3.2 in chapter three, are led in this chapter by showing them in more detail, in Figure

e 5.1

:onceptual framework Showing Antecedents and
equents of the Strategic Manufacturing Effectiveness



are two points to be made which are concerned with :ehensiveness and parsimony. The first point is whether these ısions adequately cover the domain of all possible effects of facturing effectiveness. The second point is whether they are ɔt from one another.

ding the first point, even though one cannot argue that these .sions cover all the possible antecedents that can affect facturing effectiveness, it is contended here that the five sions derived in chapter three represent the important themes ated with manufacturing's role in gaining a competitive tage for a firm. Thus each dimension has been stressed in s contexts in the literature, as outlined in chapter three, as significant in upgrading manufacturing effectiveness.

· the second point regarding the distinctiveness of the five sions, it can be argued, for example, that two of the dimensions, y, (1) the attitude of top managers towards manufacturing, and involvement of manufacturing managers in setting the strategic on of the firm, represent two aspects of the same underlying sion which can be called 'communication between acturing and top management'. However, the literature of acturing strategy does not provide persuasive arguments that suggest combining such dimensions. Thus all dimensions are y specified individually.

ties that can provide support if two dimensions are distinct or if converge towards one another and therefore should be combined. s concerning convergent and discriminant validities are ssed briefly in chapter seven, however the actual purification of mensions and their measures are presented in chapter eleven.

Research Hypotheses

ypotheses underlying this research are derived through the nation of the relationships between the seven latent variables are outlined in Figure 5.1. These latent variables are composed one latent variable that defines manufacturing effectiveness, (2) tent variables that affect manufacturing effectiveness, and (3) tent variable that represents manufacturing performance.

Figure 5.1, it can be observed that the five latent variables affect gic manufacturing effectiveness both directly and indirectly. The ey latent variables in the framework are the attitude of top gers towards manufacturing and the involvement of acturing managers in setting the strategic direction of the firm. enable the other three dimensions to influence strategic acturing effectiveness. That is because without the involvement rection of the two levels of management, it is difficult, if not sible, to create an atmosphere that lets manufacturing and unctions co-operate in such issues as strategy development and t design. Also, manufacturing managers cannot be confident to rtunity to know the kind of competitive advantage the firm is uing. Such involvement will also allow manufacturing managers nphasise more on the development of manufacturing strategy. , the first two dimensions are the basic requirements for any egically effective manufacturing function. Without them it is table that the development of this effectiveness will be at risk.

attitude of top managers towards manufacturing can also affect nvolvement of manufacturing managers in strategy debates. If top gers show interest in manufacturing, then that will encourage ıfacturing managers to know more about business strategy and ype of competitive advantage it is pursuing. Thus, the first thesis can be stated as follows:

(H1): The attitude of top managers towards manufacturing positively affects the involvement of manufacturing managers in setting the strategic direction of the firm.

managers can also influence the relationships between ıfacturing and other functions. If they show interest in ıfacturing, then it is very conceivable that they will encourage it ommunicate with other functions in such matters as the opment of strategy and product development.

the involvement of manufacturing managers in setting business egy, which is the other key variable, is very important in the that it allows the managers to know exactly what is required of ıfacturing as a function in its contributions towards the execution of business strategy. That necessitates that manufacturing managers take a leading role in the efforts of co-ordination between manufacturing and other functions. So, the second hypothesis is stated as follows:

> **(H2): Co-ordination between manufacturing and other functions is positively affected by both the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firm**

Likewise, if top managers show interest in manufacturing and the manufacturing managers are involved in business strategy development, then it is inevitable that they must formulate a functional strategy for manufacturing. Thus the third hypothesis is stated as follows:

> **(H3): The emphasis on formulating manufacturing strategy is positively affected by both the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firm**

The breadth and depth of knowledge gained from the involvement in business strategy development will also lead manufacturing managers to be more proactive in their methods of acquiring new technologies and manufacturing practices even before their importance is fully apparent. Moreover, the emphasis on formulating manufacturing strategy can contribute to the proactiveness of manufacturing. Thus, the next hypothesis can be stated as follows:

> **(H4): Manufacturing proactiveness is positively affected by the involvement of manufacturing managers in setting the strategic direction of the firm and the emphasis on formulating manufacturing strategy.**

The five latent variables all affect the degree of strategic manufacturing effectiveness. These influences can be either directly or indirectly through the compound influence of one latent variable over others as theorised in the previous four hypotheses. So, the fifth hypothesis is stated as follows

> **(H5): Strategic manufacturing effectiveness is positively affected by (1) the co-ordination between manufacturing and other functions, (2) the emphasis on formulating manufacturing strategy, and (3) manufacturing proactiveness**

The sixth hypotheses relates strategic manufacturing effectiveness to manufacturing competence. It is hypothesised that there is a positive relationship between the two. Thus, it can be stated as follows

> **(H6): Manufacturing competence is positively affected by strategic manufacturing effectiveness**

The six hypotheses deal with the structure of Wheelwright and Hayes (1985) framework. They attempt to identify those factors that measure strategic manufacturing effectiveness and its causes and outcomes. The interactions between these factors define which one of the four stages a firm is in. However, the existence of these four stages has never been investigated before. Are these stages really conspicuous and identifiable? This enquiry forms the basis of the next hypothesis which can be stated as follows:

> **(H7): There are four identifiable stages in strategic manufacturing effectiveness as specified by Wheelwright and Hayes (1985).**

The last hypothesis is related to the effects of mediating variables on strategic manufacturing effectiveness. Samson and Sohal (1993) asked that by

> 'using the Hayes and Wheelwright four-stage framework, do stage 3 and 4 firms which have a well developed strategic role of the manufacturing function outperform stage 1 and stage 2 firms? Is this effect pervasive across industry and company size? Does it apply to the same extent across different processes...?' (p. 227).

Therefore, this hypothesis can be decomposed into three sub-hypotheses and stated as follows:

> **(H8): There are differences in manufacturing performance among the four stages with respect to:**
>
> **(H8a): the type of industry,**
>
> **(H8b): the size of the firm,**
>
> **(H8c): the type of production process used.**

5.6: Summary

The focus of this chapter is the development of a conceptual model and the derivation of relevant research hypotheses. Prior to addressing these objectives, two important issues are discussed: the use of unobservable variables and causal analysis.

With the possibility of deriving the dimensions of strategic manufacturing effectiveness framework either *a priori* or *a posteriori*, the *a priori* approach is chosen because most of the dimensions were recognised previously by Wheelwright and Hayes (1985).

The conceptual framework itself is built around three inter-related elements which outline that (1) manufacturing decisions and choices that a firm makes can be used to represent the level or stage of strategic manufacturing effectiveness, (2) there are antecedent factors that influence strategic manufacturing effectiveness, and (3) the consequence of higher degree in strategic manufacturing effectiveness is better manufacturing performance.

Next, the hypotheses underlying this research are derived. Six hypotheses are delineated which represent the relationships between the seven dimensions in the conceptual framework. Thereafter, two more hypotheses are added. The first is concerned with the notion that there are four stages that are identifiable, and the second investigates the effects of mediating variables.

Having developed the conceptual framework and outlined the hypotheses that will be tested, the next step is to contemplate the important issues that have implications on what research methodology is to be used and how these hypotheses will be tested. However, before these issues are fully addressed, the state of empirical research in manufacturing strategy with respect to construct measurement are examined first in the next chapter.

Chapter 6:

Construct Measurement in Manufacturing Strategy Research

6.1: Overview

The field of manufacturing strategy does not have many, formally stated and fully developed scientific theories. Such theories, anyway, cannot be developed in a systematic way until there is a high degree of correspondence between the constructs underlying a theory and the method by which they are measured.

Measurement issues have been emphasised much more in other related fields. As an example, Bagozzi and Philips (1982), from the marketing field, noted that

> 'a failure to represent explicitly the degree of correspondence between measurements and concepts undermines the test of the theory' (p. 459).

The important aspect of developing measures that satisfy standard measurement criteria is that it does not only lend support to the underlying theory being tested, but also helps eliminate many measures which are suspect, thus reducing the quantity of measures being proposed in the field and at the same time improving the quality and acceptability of the remaining measures. By turning again to the marketing literature, Jocoby (1978) observed that

> 'More stupefying than the sheer number of our measures is the ease with which they are proposed and the uncritical manner in which they are accepted. In point of fact, most of our measures are only measures because someone says that they are, not because they have been shown to satisfy standard measurement criteria' (p. 91).

Thus the purpose of this chapter is to examine the application of standard measurement criteria in manufacturing strategy research.

6.2: Measuring Strategy Constructs

A primary aim of research in the social sciences is to furnish theoretical explanations for behaviour (Gray, 1994). The means of explaining such behaviour is to develop concepts and constructs, each one concentrating and explaining one particular behaviour. The interaction of constructs, through a theoretical network, with one another therefore can reveal the effects in magnitude and direction among the constructs. Kerlinger (1986) defined 'concepts' and 'constructs' as follows:

> 'A concept is a word that expresses an abstraction formed by generalisation from particulars....A construct is a concept. It has the added meaning. however, of having been deliberately and consciously invented or adopted for a special scientific purpose' (pp. 26-27).

Thus according to the above definition, such concepts like manufacturing strategy and manufacturing competence are constructs since they have been deliberately invented and adopted to have a particular meaning. However, empirical research dealing with such constructs has not emphasised important aspects of construct measurement. This shortcoming is not specific to manufacturing strategy but is conspicuous in most fields of strategic management. For example, Venkatraman (1989) noted that:

'.....state of attention to construct measurement in strategic management is inadequate. Researchers continue to propose and employ measures without corresponding tests for unidimensionality, reliability, convergent, discriminant and predictive validity (Venkatraman and Grant, 1986). In the absence of a systematic basis to evaluate the adequacy of measurements, confidence in research results is considerably eroded, which implies that the managerial implications derived from such results may be questionable'. (p. 944)

As for the field of operations management, Chase (1980) surveyed articles in OM journals and noted that:

'...OM research is far less sophisticated in terms of alternative research designs employed than is that reported in such research journals as the Administrative Science Quarterly, the Academy of Management Journal, or the Journal of Applied Psychology' (pp. 13).

Eleven years later, Swamidass (1991) observed that:

'An inspection of published field-based empirical articles by OM researchers shows that they are predominantly exploratory and use the most rudimentary form of analysis' (p. 797).

These two views support the assumption that the progress of manufacturing strategy, with respect to research methodologies and measurement issues, has been slow. A recent review of empirical research in manufacturing strategy by Minor *et al.* (1994) indicated that things have not improved considerably. To overcome this lack of methodological rigour, Minor *et al.* (1994) suggested that future studies in manufacturing strategy should have the following characteristics:

- They must be reproducible.
- Methodological details must be described sufficiently.
- Studies must build upon previous efforts to progress the field into new grounds.

The underlying theme for the above characteristics is that there is a need for sound research methodologies to be utilised, because as Hughes *et al.* (1986) indicated

> 'Tests of substantive theory (i.e., hypothesised relationships among theoretical constructs) necessarily involve an "auxiliary measurement theory" (Blalock, 1982, p. 25) concerning relationships among theoretical constructs and their indicators. When the auxiliary measurement theory is strong, empirical analysis can lead to a greater understanding of the phenomenon under investigation. However, weak associations between theoretical constructs and observed variables may lead to incorrect inferences and misleading conclusions about relationships among the underlying theoretical constructs of interest' (p. 130).

Scholars responded to the need for a high degree of correspondence between constructs and their measures by proposing recommendations for improving the reliability and validity of the scales used. Churchill (1979), for example, suggested following a paradigm that he proposed for developing better measures for constructs. Some other scholars like Bagozzi (1980) introduced more powerful statistical techniques such as structural equation modelling, at an early stage of its development, to the marketing field and from there to other branches of management. This specific technique contributed positively to the proliferation of the importance of satisfying standard measurement criteria.

Measurement issues are becoming more important in manufacturing strategy because of the numerous calls to employ empirical research which imply emphasis on quantitatively operationalised strategy constructs. During the last decade, the Manufacturing Futures Survey Project has helped the progress towards this trend.

A consequence of this trend is that it can improve the quality of descriptive research in manufacturing strategy. That can be achieved through the reduction or elimination of the tendency to prescribe prematurely without first giving enough thought and attention to understanding the phenomenon being tested. As Mintzberg (1987) testified

> 'There has been a tendency to prescribe prematurely in management policy - to tell how it should be done without studying how it is done and why...Prescriptions become useful only when it is grounded in sophisticated description' (pp. 91-92).

An assessment of the empirical manufacturing strategy research which is reviewed by Minor *et al.* (1994) reveals three distinct issues:

First, there is no consistency in the definition of constructs and the assessment of their dimensionality.

Second, researchers in the field, fortunately, have employed multiple items and used interval scales in their studies. However, there are some who still utilised nominal and/ or single item scales. Thus, the pitfalls of using nominal and/ or single item scales will be examined.

Third, validity and reliability of measures are not assessed adequately.

Each of these three issues are explained in detail below.

6.3: Inconsistency in Construct Definition

Defining a construct clearly and concisely is the first step that should be taken in order to develop better measures for that construct (Churchill, 1979). Clarity in defining a construct makes it possible for a study to be reproducible and that can facilitate for the construct to be verified and extended if needed. A cumulative body of literature can then be built because as Churchill (1979) commented

> 'definitions of constructs are means rather than ends in themselves. Yet the use of different definitions makes it difficult to compare and accumulate findings and thereby develop syntheses of what is known' (p. 67).

Another important advantage of having clear definitions of constructs is that it helps in choosing the dimensions of a construct and assigning measures to the dimensions (Bollen, 1989).

The situation in manufacturing strategy with respect to consistency of construct definitions is best described by Leong *et al.* (1990) who in their review of research in manufacturing strategy noted that 'writers in the field of manufacturing strategy have been casual about establishing their work in the context of what has been previously written. A large part of the price paid for this lack of scholarship in the field is a general inability of scholars in the field to communicate their ideas adequately. A review of the literature quickly reveals that different authors often discuss the same underlying construct but using different terminology' (p. 118).

6.4: Employing Nominal and Single Item Scales

Researchers (e.g., Flynn *et al.*, 1990) noted that there are four types of scales that can be utilised as shown in Table 6.1. Even though the majority of the studies, reviewed by Minor *et al.* (1994), used interval scales [represented by the Likert scales], some used nominal scales.

The disadvantages of using nominal scales are many. While these scales are adequate in the early stages of operationalising constructs, they cannot show differences within a particular group of subjects being studied. Moreover, they cannot be used in many statistical analyses which require at least an interval scale. Thus, inferences that can be made from nominal scales are very limited.

The other issue is the usage of single item scales. Because of the complexity of constructs in the social sciences, one single item cannot adequately convey the meaning of a concept (Nunnally, 1978). The reasons, as Churchill (1979) observed, are that any single item is necessarily unique which means that if it is used by itself to measure a construct then it will have low correlation with it. Also, single items do not individually produce reliable responses because even if a single respondent is given the chance to answer a single question twice, at two different but close points in time, it is not likely that he or she will have the exact same answer. Thus, any single item is susceptible to systematic as well as random errors which will lower its reliability and validity to capture the broader concept that is being measured.

Table 6.1
Types of Measurement Scales
Adapted from Flynn *et al.* (1990), p. 259

Scales	interpretation
Nominal scales	assign observations to data (Best, 1970). For example, respondents may be asked to check the quality techniques they understood. Their choices cannot be placed in a specific order.
Ordinal scales	indicate relative rank, or order, among the categories. For example, respondents may be asked to rank their strategic manufacturing goals. Ordinal measures have no absolute values, and the differences between adjacent ranks may not be equal.
Interval scales	can be ranked, and the differences between the ranks are equal. The widely used Likert scale is an example of an interval scale. Interval measures may also be added or subtracted. For example, Likert scale responses are frequently added to form a summated scale. However, since a Likert scale has no true zero, responses cannot be related to each other as multiples or ratios.
Ratio scales	have all of the properties of the three types of [scales] mentioned above, as well as a true zero and all of the qualities of real numbers. Thus, ratio [scales] can be added, subtracted, multiplied and divided. It is mostly gathered from factual, archival sources; ratio scales designed to gather opinion data are not readily available.

Single item scales can be used if two assumptions are met: a construct is unidimensional, and is measured with very little error (Nunnally, 1978). However, in reality such constructs are few. The inadequacy of single item scales is vividly captured by Jacoby (1978) who complained that

> 'what makes us think we can use responses to single items (or even two or three items) as measures of these concepts, then relate these scores to a host of other variables, arrive at conclusions based on such an investigation, and get away with calling what we have done 'quality' research?' (p. 93).

Because of the limitations of single-item scales, multi-item scales should always be used instead. Such scales have the potential of overcoming the shortcomings of single item scales. The reliability of scales is increased when the number of items is increased. Systematic and random errors associated with each single item are averaged and thus minimised for multi-item scales.

The review by Minor *et al.* (1994) shows that most of the studies used multiple items to define the concepts being studied. However, validity and reliability issues are generally not examined as the next section describes.

6.5: Inadequate Assessment of Validity and Reliability

Bagozzi (1980) and Bagozzi and Phillips (1982) recommended two types of analyses which must be carried out to assess the validity and reliability of measurement instrument. The first type of analysis is called internal consistency of operationalisation which refers to two kinds of tests. They are unidimensionality and reliability (Venkatraman, 1989). The purpose of unidimensionality is to assess that each item measures the theoretical construct. This test is carried out using exploratory factor analysis or confirmatory factor analysis as implemented in the LISREL framework (Joreskog and Sorbom, 1978). Reliability measures the extent to which a questionnaire, summated scale or item which is repeatedly administered to the same people will yield the same results. Thus, it measures the ability to replicate the study. Cronbach's Alpha is usually used for testing the reliability of the instrument. The reliability coefficients of structural equation modelling technique can also be used.

The second category of analysis is concerned with validity. The two types of validity that are mostly conducted are convergent and discriminant validity. Convergent validity is an evaluation of the uniformity in measurement over multiple operationalisations. It can be assessed through correlation analysis, multi-trait multi-method matrix, or structural equation modelling. Discriminant validity is an assessment that the measure does not associate with another measure from which it should differ (Venkatraman, 1989). Discriminant validity is assessed with the same techniques used for examining convergent validity. If structural equation modelling is used, then discriminant validity is confirmed for any two pairs of dimensions if they are correlated and found to differ significantly from unity (Sethi and King, 1994).

Almost all of the studies reviewed by Minor *et al.* (1994) did not satisfy standard measurement criteria as shown in Table 6.2. The importance of assessing validity in the research process is stressed by many researchers. For example, Peter (1979, p. 6) stated that:

> 'Valid measurement is the *sine qua non* of science. In a general sense, validity refers to the degree to which instruments truly measure the constructs which they are

intended to measure. If the measures used in a discipline have not been demonstrated to have a high degree of validity, that discipline is not a science'.

Table 6.2
Approaches Used for Manufacturing Strategy Measurement
(Names of researchers and the focus of studies is adapted from Minor, 1994)

Researchers	Focus of study	Measurement tests
Anderson *et al.* 1991	Manufacturing strategy process and its relationship to business strategy process	None
Cleveland *et al.* 1989	Production competence and its relationship to strategy, process, and performance	None
De Meyer and Ferdows 1987	Dimensions that define and categorise strategies for manufacturing	None
De Meyer *et al.* 1989	Manufacturing strategy concerns among European, Japanese, and US manufacturers	None
De Meyer and Ferdows 1991a	The state of European manufacturing on the eve of Europe 1992	None
De Meyer and Ferdows 1991b	The current state of manufacturing strategy among European manufacturers	None
Ferdows *et al.* 1986	Comparison of strategic priorities among European, Japanese, and US manufacturers	None
Ferdows and Lindberg 1987	Comparison of FMS firms to non-FMS firms, and the broader impact of FMS on strategies	None
Ferdows and De Meyer 1990	The nature of trade-offs among manufacturing competitive capabilities	None
Galbraith 1990	Role of intra-firm technology transfers in attainment of flexibility and plant focus	None
Horte *et al.*1987	Examination of competitive priorities and concerns of Swedish manufacturers	None
Horte et al 1991	Assessment of strategic directions and competitive means among Swedish manufacturers	None
Lindberg 1990	Integration of technology, work organisation, and production system plans to the strategic capabilities of manufacturing	None
Lindberg and Trygg 1991	Consistency between suppliers' manufacturing strategies and weaknesses in supplier-manufacturer relationships	None

Table 6.2, Continued

Researchers	Focus of study	Measurement tests
Reitsperger and Daniel 1990	Comparison of top managerial philosophy towards operations strategy in Japan and US firms	None
Richardson *et al.* 1985	Degree of congruence between corporate and plant missions, and degree of corporate/plant focus on corporate performance	None
Schmenner 1982	Multiple-plant manufacturing strategies among Fortune 500	None
Schroeder *et al.* 1986	How MS is defined, identification of strategies, and content elements of MS	None
Schroeder *et al.* 1989	Definition, measurement, and improvement of manufacturing innovation	None
Swamidass 1986	Comparison of CEOs and manufacturing managers' views towards MS	None
Swamidass and Newell 1987	The effect of environmental uncertainty on manufacturing flexibility and the role of manufacturing managers	Only reliability was tested
Tunalv 1990	Relationship between the degree of decentralisation and manufacturing strategy	None
Utterback & Abernathy 1975	The relationship between product strategy, innovation, and production process development	None

Part of the reason for this lack of attention towards the assessment of validity and reliability of measures is that most researchers in the field emphasise substantive relationships and implicitly think that their measures are adequate. However, this implicit assumption regarding the adequacy of their measures can seriously hamper the progress of the field.

6.6: Summary

This chapter has highlighted the need for a high degree of correspondence between the constructs underlying a theory and the method by which they are measured. This need is even more crucial for our field because the importance of construct measurement has not been grasped by empirical researchers in manufacturing strategy. The evidence is that previous studies did not take measurement issues at the core of their investigations.

This situation is changing, albeit slowly. Many recent studies have started to show more methodological details, and satisfy standard measurement criteria. One example of such studies is that of Flynn *et al.* (1994) who developed a framework for quality management research and an associated measurement instrument.

In summary, three critical issues are identified which are related to construct measurement. They are:

<u>1- the consistency of construct definition</u>

Defining a construct concisely is a necessary but not sufficient condition for developing better measures for that construct. It makes studies with such constructs reproducible and verifiable, and so a cumulative body of literature can be built.

<u>2- using interval and multi-item scales</u>

Most of the empirical studies in manufacturing strategy, fortunately, used interval and multi-item scales. Such scales have the capacity to show 'within-group' differences and can be used in many statistical analyses.

<u>3- the significance of assessing validity</u>

On the other hand, the majority of studies did not satisfy standard measurement criteria. The importance of assessing validity and reliability in the research process is that it shows whatever random and systematic errors there are in the study so that corrective measures can be taken.

The identification, in this chapter, of pitfalls that are usually associated with empirical studies will help in the selection of an appropriate research methodology that can avoid such obstacles. That is the topic of the next chapter.

Chapter 7:

Research Methodology

7.1: Overview

Leong et al (1990) in their review of manufacturing strategy observed that the field is progressing slowly due to: (1) lack of survey-based empirical work, (2) the dearth of cohesive efforts towards theory building, and (3) researchers failing to adopt ideas from the more developed and related disciplines.

With respect to the first reason regarding the scarcity of empirical studies in manufacturing strategy, Flynn *et al.* (1990) commented that the reasons behind it are:

- The high expenses that are usually associated with undertaking empirical studies. Financial and time resources are required for satisfactory questionnaire design and data gathering procedures.
- It is difficult to get the commitment of respondents and that can require a lot of time and persuasion.
- In the academic environment, academicians are under pressure to produce papers. The traditional methods of mathematical formulation and simulation studies are found to be faster for this purpose.
- Empirical studies have been viewed with less esteem in the field of operations management. The importance of empirical research has not been grasped.
- Many researchers are not aware of the existence of sound data collection methods and powerful statistical analysis tools.

The second reason for the slow progress of manufacturing strategy is the dearth of cohesive efforts towards theory building. This is evident from the various studies which failed to provide a consistent and clear definition of manufacturing strategy (Anderson *et al.*, 1989). There are many other semantic differences in the literature. For example, Booz Allen and Hamilton (1982) used the term 'manufacturing mission' to denote what Skinner (1969) called, more than a decade earlier, 'the manufacturing task'. Thus the challenge for the field of manufacturing strategy as Anderson *et al.* (1989) commented is

> 'to advance the field by reducing unnecessary semantic differences, and sharpening our understanding of the potential real alternative differences' (p. 137).

The last reason identified by Leong et al (1990) as contributing to the slow advancement of manufacturing strategy is that researchers are not adopting ideas from the more developed and related disciplines. Swamidass (1989) earlier had suggested that researchers in our field should look at related fields like business strategy because

> 'By ignoring business strategy literature, we stand the risk of reinventing the wheel or missing out on existing concepts of potential value for the development of the manufacturing strategy area. By integrating the two literatures, manufacturing strategy can be enriched' (p. 264).

Other fields can enrich not just the content of manufacturing strategy, but also the methods we use to do research. For example, the importance of valid and reliable measures has been stressed by many researchers in various disciplines. Yet there is a lack of empirical studies in manufacturing strategy which have implemented such measures as pointed out in the previous chapter.

The factors, presented above, reveal the extent of difficulties associated with empirical research. That is why there is a need to follow proven and systematic approaches in the development of construct measures and hypotheses testing. The next section gives details for such an approach.

7.2: Procedure for Developing Measures

One of the widely cited approaches for the development of measurement instruments is that provided by Churchill (1979). This paradigm has found broad acceptance in many fields of research. For example, Sethi and King (1994) used this paradigm to develop measures for assessing the extent to which information technology applications provide competitive advantage. The paradigm consists of eight steps which are described below:

- Step 1. Specifying the domain of construct:

In this step, the construct is defined constitutively and operationally. Constitutive definition means defining the boundary of the construct by delineating it from other similar constructs. Operational definition gives the construct a meaning through designating activities that will measure it.

- Step 2. Generating sample of items:

In this step, dimensions of the construct and the items that associate with each dimension are derived. The derivation procedure includes literature searches and experience surveys. After the items have been identified, they are then edited. One example of editing is when dealing with a double- barrelled statement. Such statement must be split into two, or eliminated altogether. At that point, the items are included in a questionnaire, where some will be positively worded and some will be negatively worded so that tendencies to say 'yes' or 'no' on all statements are reduced.

- Step 3. Collecting data:

This is the first stage of data collection. The purpose is to expose the items to further refinement as detailed in the next step.

- Step 4. Purifying measures:

In this step, the items are examined empirically to verify the absence of measurement errors. This examination is called the reliability assessment. One of the tests that can be used to assess the reliability of an instrument is split-half correlation. However, the most widely used test is the internal consistency reliability using Cronbach's Alpha. In order for the Alpha test to provide an unbiased estimate for reliability, the items must be unidimensional. Unidimensionality can be defined as the existence of one latent trait or construct underlying a set of measures (Hattie 1985; McDonald 1981). In simple terms, unidimensionality means that each item should measure only one dimension, and each dimension should measure the construct independently of other dimensions. Usually, confirmatory factor analysis is used to examine the dimensionality of a construct.

• Step 5. Collecting data:

The purpose of the second data collection exercise is to cross-validate the findings from the initial data collected in step 3. This will give research some confidence that the findings from the first data collection are not due to chance.

• Step 6. Assessing reliability:

In this step, the same reliability tests in the purification step have to be carried out again. Moreover, other tests like the test-retest reliability can be used.

• Step 7. Assessing validity:

Reliability tests are a necessary, but not sufficient, condition for verifying the validity of the instrument. Validity in general terms means that the instrument measures what it sets out to measure (Carmines and Zeller, 1979). The validity of a construct is confirmed through convergent and discriminant validity. Convergent validity is achieved when the measure of the construct correlates highly with similar measures that are designed to measure the same construct. Discriminant validity is attained when the measure of the construct does not correlate highly with other measures that measure different constructs. Traditionally, multitrait-multimethod matrices, proposed by Campbell and Fiske (1959) are used to assess convergent and discriminant validity. However, in recent studies in the social sciences, structural equation modelling has been applied in the process of assessing convergent and discriminant validity.

- Step 8. Developing norms:

After a reliable and valid measure has been achieved, the last step is to use the raw scores as input into descriptive statistics like calculating the mean, and the standard deviation, or use the scores for inferential statistics according to the hypotheses that are being tested.

Churchill's paradigm is utilised for this research. However, it is adapted in the following way:

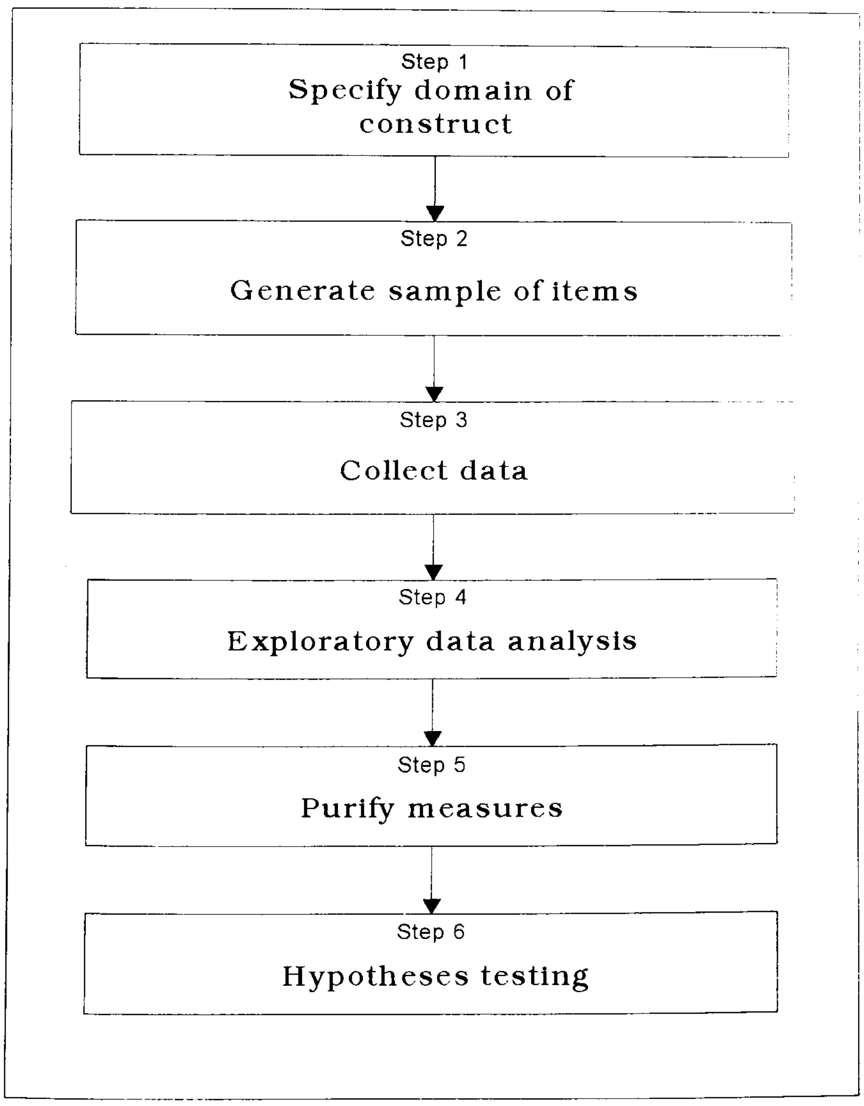
- The data is collected just once which means that steps 3 and 5 are combined.
- Step 4, purifying the measures, step 6, the assessment of reliability, and step 7, the assessment of validity, are combined into one step.
- After collecting the data and before the measures are purified, there is an important phase of data analysis which is called exploratory data analysis. This phase is included as a step in the adapted paradigm.

Thus the revised Churchill's paradigm is shown in Figure 7.1, and with reference to this figure:

- step 1, which calls for specifying the domain of the constructs, was conducted in chapters three through five.
- As for step 2, i.e. generating sample of items, that is the theme of the next chapter, which is chapter eight.
- Issues related to data collection, step 3, are discussed in chapter nine.
- Data exploration, step 4, is performed in chapter ten.

- As for step 5, purification of the measures is documented in chapter eleven. Prior to that in the next section of this chapter, however, the main method of purifying the measures is briefly presented. The focus of this presentation is on the applicability and merits of the statistical technique known as structural equation modelling as implemented in LISREL.
- Finally, for step 6, the hypotheses are tested in chapter twelve.

Figure 7.1
Procedure for Developing Measures
Adapted from: Churchill, 1979



7.3: Purifying the Measures Through LISREL

The measurement attributes of a construct, from a theoretical standpoint, are evaluated through numerous criteria. Examples of these are theoretical meaningfulness, internal and external validity, internal consistency of operationalisation, convergent validity, discriminant validity, and predictive validity (Bagozzi 1980). However, from an operational standpoint, Venkatraman (1989) suggested that, for newly developed measures, the following criteria are considered sufficient: reliability, unidimensionality, convergent validity, and discriminant validity.

The traditional method of assessing reliability and validity is to use Cronbach's Alpha, exploratory factor analysis, and bivariate correlations (Steenkamp and van Trijp, 1991), then apply path and regression analysis to find the relationships among constructs and their measures (Gregson, 1992). To test for convergent and discriminant validity, multitrait-multimethod matrix of Campbell and Fiske (1959) is usually employed. However, research in the social sciences, in the last decade, has witnessed a move toward using a statistical technique called structural equation modelling.

Structural equation modelling (SEM), also called covariance structure analysis, is a general linear modelling technique which has its roots in factor and regression analysis. SEM is considered a confirmatory, rather than exploratory, technique. That is, a researcher will employ SEM to decide if a specific model is consistent with his or her data, rather than using SEM to find a suitable model. SEM has the following advantages:

1. It allows latent constructs to be represented by multiple measures (e.g., Martin, 1987). This is desirable in such fields as manufacturing strategy where there is a need to represent multidimensional constructs. The utilisation of multiple indicators can contribute to the proliferation of more valid and reliable evaluations of latent constructs. In addition, utilising latent variables can permit researchers to employ a small number of exploratory constructs to explain phenomena.
2. It can assess the reliability and validity of constructs and their relationships among one another and with their measures simultaneously (Steenkamp and van Trijp, 1991).
3. It takes into account measurement errors in the models under study (Martin, 1987).
4. It can handle interval as well as ordinal data (Joreskog and Sorbom, 1989).
5. SEM has the capacity to manipulate very complex, multivariate models, specially in non-experimental research which does not have well developed techniques for testing such models that are primarily based on latent variables (Bentler, 1980). Such a utilisation of SEM can lead to the enhancement of our capability to draw causal inferences.

With respect to the last advantage which really sets SEM apart from other statistical techniques, Bullock *et al.* (1994), assessing the relationship between SEM and causality, noted that

> 'Although using latent variables may increase ambiguity, making causal inferences difficult, they also allow complex

theories to be tested. Our world is a complex place, and, if causal evidence is ever to be effectively acquired, it will only be through designs and statistical procedures that can take such complexity into account' (p. 262).

Because of the advantages of SEM over other traditional methods, this research utilised this relatively new technique to develop a measurement instrument for the strategic manufacturing effectiveness construct and its antecedents and consequents. It is worth noting in this respect that even though SEM has been applied quite extensively in such fields as psychology and marketing for model development, it has yet to have wide acceptance in operations management. One of the earliest studies to utilise SEM in operations management is that of Sharma (1987). Thereafter, there was a gap of around seven years until some SEM-based studies appeared again in the literature. Two examples of these recent studies are that of Maani *et al.* (1994) who employed it to develop a model that relates quality to performance, and the work of Germain and Droge (1995) who utilised LISREL to test a model of factors that predicts electronic data interchange (EDI) technology adoption.

7.4: Summary

The field of manufacturing strategy has progressed slowly due to many factors such as the lack of empirical studies, the dearth of cohesive efforts towards theory building, and the failure to adopt ideas from the more developed disciplines. However, the small body of empirical studies in the field, with all its contributions during the last two decades, suffers from its lack of methodological rigour. So, in order to avoid this pitfall, this research follows a research methodology that is based on the widely used paradigm for the development of measurement instruments formulated by Churchill (1979). This adapted paradigm consists of six steps. They are (1) defining the domains of the dimensions, (2) generating items to measure the dimensions, (3) collecting data, (4) exploring the data, (5) purifying the measures, and (6) testing the hypotheses.

Step 1, defining the domains of the dimensions, was accomplished in chapters three through five, and the rest of the five steps are discussed in the next chapters consecutively. However, because the procedure that is used to purify the measures is not widely used in operations management, the rest of the chapter examined the statistical technique, called structural equation modelling, and its appropriateness for this type of research.

SEM is a general linear modelling technique that is usually used in a confirmatory manner to determine if a specific model is consistent with data. As outlined earlier, it has many advantages over other traditional methods. SEM is implemented in many software packages, however the first programme and the most popular is called LISREL, which is used in this research.

Following the adapted six step paradigm of Churchill (1979), the next chapter focuses on operationalising the dimensions by generating items to measure them.

Chapter 8:

Operationalisation of the Constructs

8.1: Overview

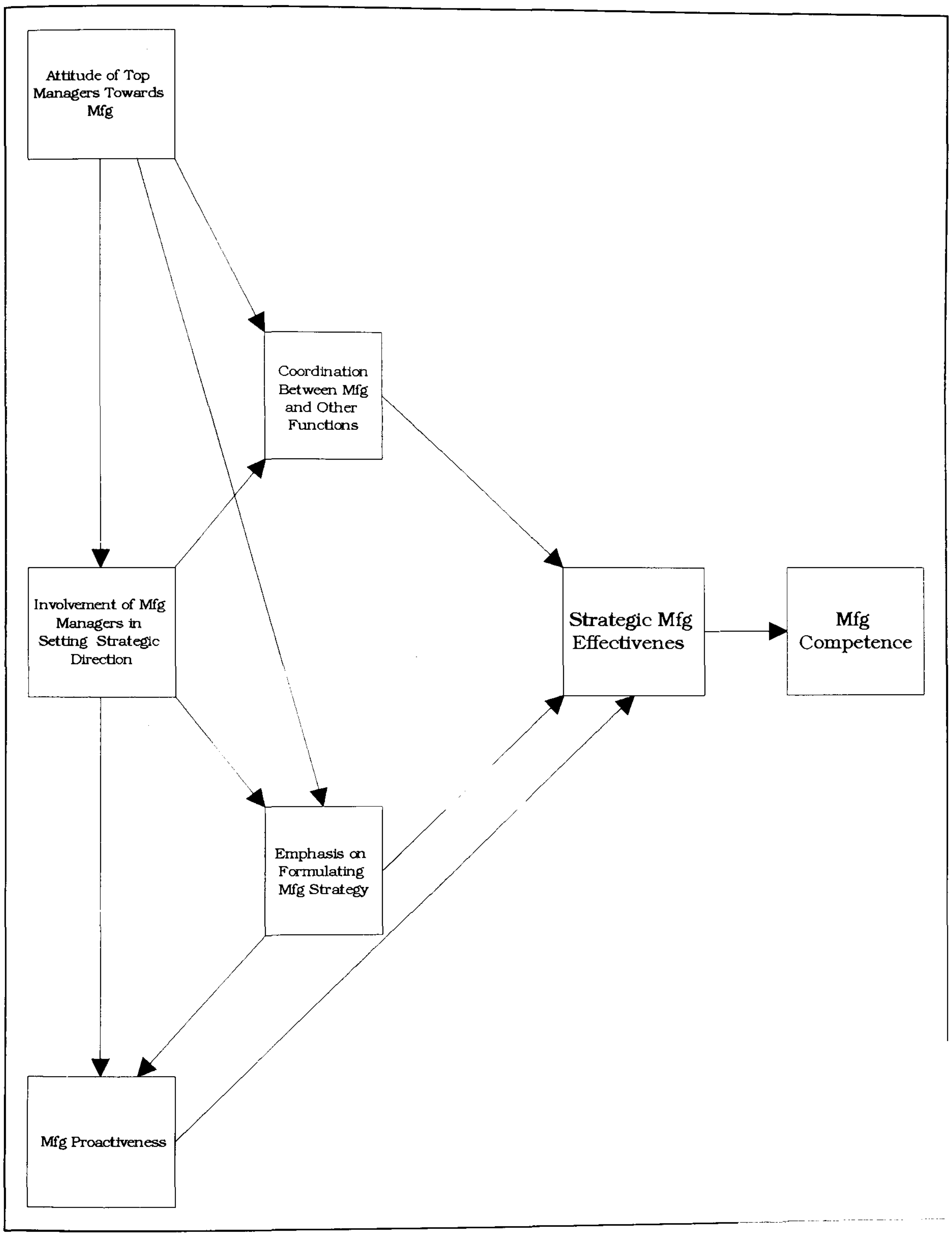
In the previous chapter, an adapted framework of Churchill's paradigm for developing measures was presented. After specifying the domains of the constructs in step one, this adapted paradigm, in step two, calls for operationalising these constructs by generating items to measure them. This process is the focus of this chapter.

The theoretical framework, which is depicted in Figure 5.1, and repeated here as Figure 8.1, forms the basis for generating the manifest variables. It shows seven constructs in a theoretical network. Five of these are the dimensions that affect strategic manufacturing effectiveness, and one construct called 'manufacturing competence' is a measure of manufacturing performance.

In the following sections of this chapter, indicators are generated for each construct. During the process of generating the indicators, two points, which were suggested by Swamidass and Newell (1987), are followed. The first point is that only the items that are theoretically supported must be included as indicators (Asher, 1981; Heise, 1975). The second point is that the number of indicators must be kept to a minimum (Young, 1977).

There are two main advantages of reducing the number of indicators. One is that by presenting to potential respondents a more manageable questionnaire, the chance of achieving a higher response rate is increased. However the more important advantage is that building a theoretical model with less items can help in the interpretation of the results (Bentler and Chou, 1987).

Figure 8.1
Antecedents and Consequents of the Strategic Manufacturing Effectiveness.



8.2: Indicators for Strategic Manufacturing Effectiveness

The items that represent strategic manufacturing effectiveness are based on the list of manufacturing improvement programmes which was compiled by Ferdows and DeMeyer (1990) and other researchers working in the Manufacturing Futures Survey Project. This list is shown as Table 3.6 in chapter three. The number of indicators in this list is thirty nine. From an empirical point of view, this number is considered to be too high. Hence an effort is made to strike a balance between parsimony and comprehensiveness.

That is necessary in order to eliminate those items that are repetitive and also delete the ones that are general and cannot be easily interpreted.

Examples of items that are repetitive are job enrichment, giving workers more planning responsibility, and giving workers a broad range of tasks. With respect to these three indicators, only the last one is kept since it covers the other two items.

Examples of items that are deleted are manufacturing reorganisation and changing labour- management relationships. These two actions are too general and the variations between firms in implementing such programmes cannot be interpreted readily. They both imply a change from one state to another, however it is not known what are the characteristics of the initial state and how different they are from the new state that has been arrived at through 'changing labour-management relationships' or 'manufacturing reorganisation'. Table 8.1 shows some of those items which are deleted and the reasons for deleting them.

Table 8.1
Manufacturing Improvement Programmes Which are Deleted

Manufacturing Improvement Programmes	Reasons for Deleting
Supervisor training	This item is represented by 'manager training'
Changing labour management relationships, Manufacturing reorganisation, Reducing size of manufacturing units	These items are too general and might not be applicable to a wide range of firms, and the variations between firms are not easily interpretable.
Automating jobs, Group technology, Robots	For reasons of parsimony, these items are deleted and only one item is kept which is 'implementing FMS' to represent the implementation of advanced manufacturing technology.
Giving workers more planning responsibility, job enrichment	These items are represented by 'giving workers a broad range of tasks'.
Reducing set-up/ changeover time, Vendor lead-time reduction	These items are represented by 'manufacturing lead-time reduction'.

Thus the complete list of manufacturing improvement programmes that are used to indicate strategic manufacturing effectiveness are those shown in Table 8.2.

Table 8.2
Manufacturing Improvement Programmes Which are Used to Represent Strategic Manufacturing Effectiveness
Source: Ferdows and De Meyer (1990)

No.	Manufacturing Choice
Str1	Manufacturing lead time reduction
Str2	Just-in-Time (JIT)
Str3	Introduction of Flexible manufacturing systems
Str4	introduction of CAD/CAM
Str5	Developing new processes for new products
Str6	Developing new processes for old products
Str7	Capacity expansion
Str8	Reconditioning of physical facilities
Str9	Reducing the size of manufacturing work force
Str10	Plant relocation or closing plants

Str11	Management training
Str12	Worker training
Str13	Worker safety
Str14	Giving workers a broad range of tasks
Str15	Statistical quality control
Str16	Vendor quality
Str17	Zero defects
Str18	Quality circles
Str19	Preventive maintenance
Str20	Integrating systems across areas
Str21	Integrating systems within manufacturing
Str22	Improving new product introduction capability

8.3: Indicators for the Five Dimensions Affecting Strategic Manufacturing Effectiveness

The five dimensions were identified previously as being the attitude of top managers towards manufacturing, the involvement of manufacturing managers in setting the strategic direction of the firm, the emphasis on formulating manufacturing strategy, manufacturing proactiveness, and co-ordination between manufacturing and other functions.

These five dimensions have been thoroughly examined in chapter three, and the indicators for each dimension are directly derived from that chapter. Readers are therefore requested to refer to chapter three for more details about the indicators. The rest of this section presents the indicators for each dimension separately.

8.3.1: The Attitude of Top Managers Towards Manufacturing

This dimension is stressed by Wheelwright and Hayes (1985) during their presentation of the characteristics of the four stages in their framework. They observed that top managers in stage one firms consider manufacturing to be neutral and incapable of influencing competitive success. Top managers try also to minimise their involvement with and dependence on manufacturing.

In stage two firms, they encourage manufacturing to follow industry practice, and view economies of scale as the most important source of production efficiency. They also consider resource allocation decisions to be the best way of addressing major strategic concerns in manufacturing.

Table 8.3
Indicators for the Attitude of Top Managers Towards Manufacturing
(source of the indicators is Wheelwright and Hayes, 1985)

No.	Indicators	Effect
Att1	Top managers consider manufacturing to be neutral and incapable of influencing competitive success.	(-)
Att2	They minimise their involvement with, and thus their perceived dependence on, manufacturing.	(-)
Att3	They encourage manufacturing to follow industry practice in matters regarding the work force, equipment purchases, and capacity additions.	(-)
Att4	They view economies of scale related to the production rate as the most important source of manufacturing efficiency.	(-)
Att5	They regard resource allocation decisions as the most effective means of addressing the major strategic issues in manufacturing	(-)
Att6	They communicate frequently with the manufacturing managers to understand the problems facing manufacturing and help to solve them	(+)

In higher stages, top managers make efforts to communicate as often as they can with the manufacturing managers in order to understand the problems facing manufacturing and help to solve them. These observations formed the basis for six indicators that are supposed to measure the attitude of top managers towards manufacturing. They are shown in Table 8.3 in the previous page.

8.3.2: The Involvement of Manufacturing Managers in Setting the Strategic Direction of the Firm

Table 8.4 shows five indicators which are hypothesised to measure this dimension. Wheelwright and Hayes (1985) provided the first indicator through their observation that manufacturing managers in stage three and four firms seek to understand their company's business strategy and the kind of competitive advantage it is pursuing.

Table 8.4
Indicators for the Involvement of Manufacturing Managers in Setting the Strategic Direction of the Firm
(source of the indicators is Hill (1993) unless otherwise stated)

No.	Indicators	Effect
Inv1	Manufacturing managers seek to understand their company's business strategy and the kind of competitive advantage it is pursuing (Source: Wheelwright and Hayes, 1985).	(+)
Inv2	Manufacturing managers view their roles as being reactive.	(-)
Inv3	Manufacturing managers involve very late in corporate policy debates.	(-)
Inv4	Manufacturing managers do not express themselves well in corporate policy debates.	(-)
Inv5	Manufacturing managers spend most of their time in dealing with day-to-day operating issues (Source: Hayes *et al.*, 1988).	(-)

Hill's (1993) findings about the role played by manufacturing managers contributed three indicators. He observed that manufacturing managers in many firms view their roles as being reactive. Moreover, they involve very late in corporate policy and when they get the chance to represent manufacturing in corporate debates they do not express themselves well.

The third source used is Hayes *et al.* (1988). They noted that manufacturing managers in stage two firms spend most of their time in dealing with day to day operating issues; whereas in stage four firms, much more time is spent on strategic concerns. Thus, Hayes *et al.* suggest that there is an inverse relationship between the amount of time a manufacturing manager spends on the day to day running of operations and his involvement in setting the strategic direction of his firm.

8.3.3: The Emphasis on Formulating Manufacturing Strategy

This dimension is measured by six indicators. The first one is the formal development of manufacturing strategy. The second one, which is related to the first indicator, is the use of outside experts to help tackle strategic issues involving manufacturing. Both of these indicators are based on the work of Wheelwright and Hayes (1985).

As shown in Table 8.5, the third indicator is based on the work of Venkatraman (1989) who developed a strategic orientation construct of business firms. This indicator is 'developing thorough analysis when confronted with a major decision'.

The other three indicators are contemplated once again by Wheelwright and Hayes (1985) who observed that manufacturing functions in stage three firms screen their decisions to make certain that they are compatible with the organisation's competitive strategy.

Table 8.5
Indicators for the Emphasis on Formulating Manufacturing Strategy
(source is Wheelwright and Hayes (1985), unless otherwise indicated)

No.	Indicators	Effect
For1	Manufacturing strategy is formally formulated.	(+)
For2	Strategic issues involving manufacturing are tackled by outside experts.	(-)
For3	Develop thorough analysis when confronted with a major decision (Source: Venkatraman, 1989).	(+)
For4	Screening decisions to be sure they are consistent with competitive strategy.	(+)
For5	Employing detailed measurements and controls of operating performance.	(-)
For6	Incorporating nonfinancial considerations in the capital budgeting process.	(+)

Moreover, in stage four, firms analyse their manufacturing decisions regarding capital investments by incorporating nonfinancial considerations. On the other hand, firms in stage one employ only detailed financial measurements and controls of operating performance. Such a system of controlling manufacturing performance has been criticised by some researchers (e.g. Kaplan, 1984) as one of the causes that can undermine production.

8.3.4: Proactiveness

The work of Venkatraman (1989) is utilised also for measuring proactiveness. Two of the indicators of his proactiveness and riskiness dimensions are found to be relevant for this dimension. They are 'constantly seeking new opportunities related to the present operations' and 'operations can be generally characterised as high-risk'.

Table 8.6
Indicators for Proactiveness
(source of the indicators is Venkatraman (1989) unless otherwise stated)

No.	Indicators	Effect
Pro1.	Constantly seeking new opportunities related to the present operations.	(+)
Pro2.	Operations can be generally characterised as high-risk.	(+)
Pro3.	Anticipate the potential of new manufacturing practices and technologies and seek to acquire expertise in them long before their implications are fully apparent (Source: Wheelwright and Hayes, 1985).	(+)

The third indicator is provided by Wheelwright and Hayes (1985) who noticed that firms which have reached stage four status acquire expertise in new manufacturing practices and technologies long before their values and importance are evident. The indicators are shown in Table 8.6.

8.3.5: Co-ordination Between Manufacturing and Other Functions

Co-ordination between manufacturing and other functions in a firm usually takes place in stage four firms. Wheelwright and Hayes (1985) observed that in such firms, there is interactive development of business, manufacturing, and other functional strategies. There are also various interactions between manufacturing and other functions in order to help such efforts as product design, field service, and sales training. This process of co-ordination can also help the transfer of 'know-how' from other functions to manufacturing and vice versa.

Positive and fruitful co-ordination does not have to be only between functions within a firm, but can extend to suppliers also. Wheelwright and Hayes (1985) noted that firms in higher stages of manufacturing effectiveness go beyond the firm's boundary and try to co-ordinate efforts with their suppliers, especially offering to help solve whatever problems their suppliers encounter which directly or indirectly involve the production and supply of their parts. Thus, four indicators are identified for this dimension and they are presented in Table 8.7.

Table 8.7
Indicators for the Co-ordination Between Manufacturing and Other Functions
(source of the indicators is Wheelwright and Hayes, 1985)

No.	Indicators	Effect
Coo1	Interactive development of business, manufacturing, and other functional strategies.	(+)
Coo2	Extensive interactions between manufacturing and other functions to facilitate product design, field service, and sales training.	(+)
Coo3	Transfer of 'know-how' from other functions to manufacturing .	(+)
Coo4	Helping suppliers to solve problems.	(+)

8.4: Indicators for Manufacturing Competence

As outlined in chapter four, manufacturing competence is measured through the importance and strength in manufacturing competitive capabilities. The progress of thinking about these capabilities is shown in Table 8.8. It is obvious that the important categories of competitive capabilities have stayed almost unchanged since Wheelwright (1978) with Buffa (1984) adding service as another category. Accordingly, the dominant categories are cost, dependability, flexibility, quality and service. They are the same ones proposed by Buffa (1984).

Table 8.8
Categories of Competitive Capabilities as Viewed by Researchers in Manufacturing Strategy

Researchers	Competitive Priorities
Skinner (1969)	Productivity, Quality, Return on investment, Service
Wheelwright (1978)	Dependability, Efficiency, Flexibility, Quality
Buffa (1984)	Cost, Dependability, Flexibility, Quality, Service
Hayes and Wheelwright (1984)	Cost, Dependability, Flexibility, Quality
Hill (1985)	Delivery, Delivery Speed, Flexibility, Price, Quality, Reliability
Hayes *et al.* (1989)	Cost, Dependability, Flexibility, Quality

This research uses the same categorisation which is operationalised, by Kim and Arnold (1993), through fifteen competitive capabilities as shown in Table 8.9.

Table 8.9
Manufacturing Competitive Capabilities
Source: Kim and Arnold (1993)

Cost:	
Mco1.	Manufacture with lower cost than competitors
Flexibility:	
Mco2.	Make rapid design changes
Mco3.	Introduce new products quickly
Mco4.	Make rapid volume changes
Mco5.	Make rapid product mix changes
Mco6.	Offer broad line of products
Quality:	
Mco7.	Manufacture with consistently low defect rates
Mco8.	Provide high performance products
Mco9.	Offer reliable products
Delivery:	
Mco10.	Provide fast delivery of products
Mco11.	Deliver products on time as promised
Service:	
Mco12.	Provide effective after- sales services
Mco13.	Provide product support effectively
Mco14.	Make products easily available (broad distribution)
Mco15.	Customise products to customer needs

8.5: Summary

The dimensions in the conceptual framework are operationalised in this chapter through the generation of items that measure them. The process of identifying the items is restricted to only those that are theoretically supported. Having a small pool of items to measure each dimension is helpful in the interpretation of the results.

The first indicators to be generated are those that measure strategic manufacturing effectiveness construct. They are based on the list of manufacturing improvement programmes which was compiled by researchers involved in the Manufacturing Futures Survey Project. After deleting some repetitive and hard to interpret items, twenty two indicators are identified for this dimension.

Next, the indicators for the five dimensions affecting strategic manufacturing effectiveness are generated, based on the work of Wheelwright and Hayes (1985) and other researchers. The details of these indicators were presented in chapter three.

With respect to manufacturing competence, it is measured through the importance and strength in manufacturing competitive capabilities. The classification of the competitive capabilities suggested by Kim and Arnold (1993) is used.

After generating the items that measure the dimensions in the framework, the next task, which is step 3 in the adapted paradigm, is to collect data. This task is the subject of the next chapter.

Chapter 9:

Data Collection Method

9.1: Overview

9.2: The Survey Method

9.3: The Key Informant Approach

9.4: Population Selection

9.5: Database of Companies

9.6: Designing the Questionnaire

9.7: The Questionnaire

9.8: Pilot Study

9.9: Mailing the Questionnaire

9.10: Summary

9.1: Overview

This chapter considers data collection procedure which is step three in the paradigm for developing measures that is adapted from Churchill (1979). Issues that are related to data collection are clarified. In particular, the following points are addressed: the choice between single or multiple informant approach; the choice of data collection method; how the population of companies is selected; the source of the information about the firms under study; the design of the questionnaire; describing the sections that compose the questionnaire; how the study is piloted, and mailing the questionnaire.

9.2: The Survey Method

There are many research designs available for empirical research. Some of these are case studies, field experiments, panel studies, focus groups and surveys (Flynn *et al.*, 1994). This thesis utilises the survey method because of its suitability for this type of research where a limited amount of data is needed from a large sample. This requirement ruled out other methods which are implemented usually in small sample studies.

There are two main types of data collection methods for research based on surveys: interviews and questionnaires. Between interviews and questionnaires, and taking into account that a large sample is needed, the questionnaire is the more practical option. However, there are other issues that determine which method is chosen over the other. Alreck and Settle (1985) suggested using the questions that are shown in Table 9.1, as a guide list for choosing either interviews or questionnaires. If the answers are mostly 'no', then using questionnaires is preferable.

Table 9.1
The choice between interviews and Mail Survey
Adapted from: Alreck and Settle, (1985)

No.	Questions	Answers
1	Does the task require interaction with the respondents?	No
2	Is there the likelihood of interaction between the tendency to respond and the issues or topics being measured or assessed?	No
3	Must the survey be conducted in a specific location, at a specific time?	No
4	The respondents cannot provide and record their own responses. Is that so?	No
5	Is it more important to collect a large amount of data from each of a limited number of respondents?	No
6	Are the respondents concentrated in a limited geographic area?	No
7	Is anonymity unnecessary?	No

As the answers to these questions are entirely negative, the questionnaire is chosen as the method of data collection.

9.3: The Key Informant Approach

The key informant approach is used in this research. This method pursues information from the 'key person' in the organisation who is most capable of responding to the items in the questionnaire. In this case, the 'key person' is the manufacturing manager, regardless of his exact title within company hierarchy. The use of single informant in empirical research in manufacturing strategy is widespread. Most of the studies reviewed in Minor *et al.* (1994) used this approach.

The key informant approach is distinguished from the multiple informant approach where more than one person's responses are solicited from each organisation. The main advantage of the multiple informant approach over the key informant approach is the richness of data that can be collected. Because of the subjectivity of some of the items in a questionnaire, getting more than one response to such items will enhance their validity. Other advantages of the multiple informant approach are discussed by Phillips (1981).

It should be noted, however, that the multiple informant approach is not always the more practical approach. This is the case when the key informant occupies a position in his company where he is the only person who can furnish reliable information. Moreover, there are disadvantages associated with the multiple informant approach which hinder its practice being as widespread as it should be. Some of these disadvantages are that it is time consuming and very expensive to implement. It consumes time because the researcher must get the commitment of at least two respondents from each organisation. It is more expensive than the key informant approach because the questionnaire must be sent to all multiple informants thereby increasing the consumption of stationery and postage.

9.4: Population Selection

The population of firms in this study is drawn from three industrial sectors: mechanical goods (SIC 32), electrical goods (SIC 34), and motor vehicles (SIC 35). The choice of these industries is based on the fact that they contain more manufacturing firms than other sectors. A large population of firms is an important consideration in this research because of the need to get a large sample to work with. Three industrial sectors were chosen because of the need to mail at least one thousand questionnaires. That target is achieved with these three industrial sectors.

The questionnaire was sent to all manufacturing firms belonging to the industrial sectors outlined above that are listed in the FAME database. Three criteria were used for sampling the companies. They must have manufacturing facilities in the United Kingdom, they must have more than one hundred employees, and they must have a turnover of more than 2 million pounds. The last two conditions are necessary in order to eliminate small companies from the sample that are not likely to complete the questionnaire. The questionnaires were directed to manufacturing plants which constitute the unit of analysis in this research.

9.5: Database of Companies

The database used for names of companies in the survey is the FAME database. FAME (Financial Analysis Made Easy) is a CDROM-based financial database for major British companies whose accounts are registered at Companies House. The database is provided and maintained by Jordan and Sons Ltd, a U.K. company specialising in the provision of company information to the business community. Information is kept for around 160,000 companies. However, detailed information is available for only 100,000 firms.

The FAME database is menu driven. It is easy to use and it allows building highly complex search structures because there is no limit to the broadening and narrowing of searches.

There are two shortcomings, however, with using the FAME database. The first one is that it does not differentiate between manufacturing companies and distributors. So, the names of non-manufacturing companies, if not wanted as is the case for this research, must be deleted manually. The second shortcoming with the FAME database is that, because of its financial bias, it does not list the names of manufacturing managers. It would have been more appropriate to address the questionnaires to each manufacturing manager by his name and exact job title.

Despite these shortcomings, there are no serious alternatives to using the FAME database. The only other alternative is to use the Kompass-UK directory which is as comprehensive as the FAME database. However, it suffers from the same problems associated with the FAME database. Moreover, it is not available in electronic format in the University. Only the hardback copies are available, and it is, no doubt, difficult and tedious to compile the names and addresses of 1200 firms from a paper-based directory.

9.6: Designing the Questionnaire

A number of measures were taken in order to increase the response rate of questionnaire. Great care was paid to the external appearance of the questionnaire in order to make it attractive. The questionnaire is made as short as practical. Clear and concise instructions were given on how to complete the questionnaire. In order to minimise the effort of completing the questionnaire, the questions were styled in such a way that the respondents need only write one word answers, or circle a number. A pre-paid addressed envelope was included to make it more convenient for the potential respondent to return the questionnaire. The respondents were given the incentive of receiving a summary of the results if they wished.

In order to avoid instrumentation bias which can jeopardise the reliability and validity of the data, the recommendations of Alreck and Settle (1985) were utilised so that the items in the questionnaire can be screened for any such bias. Table 9.2, in the next page, lists some of the obstacles that can affect instrumentation bias and how such problems were overcome.

Alreck and Settle (1985) noted that a well presented questionnaire is more likely to be answered. Hence, a great effort was taken in order to make the questionnaire appear, at first glance, as though it would be quick and easy to complete. The first page of the questionnaire contained only simple questions about the firm. The pages of the questionnaire were attached together so that they were not lost or separated from one another. All the pages were clearly numbered and arranged so respondents could follow the sequence easily. There was a title at the beginning of the questionnaire and a note of thanks, urging prompt reply, at the end. The questionnaire was divided into sections. Each section had emphasis on a single theme.

Table 9.2
Avoiding Instrumentation Bias
Adapted from : Alreck and Settle (1985)

No	Obstacles	Remedies
1	Does the question state the criterion for answering?	The criterion must be clearly indicated.
2	Is the question applicable to all respondents?	It must be reworded or some respondents exempted by using a detour around it.
3	Does the item contain an example that is also a possible answer?	If so, change or discard the example.
4	Does the question require respondents to remember too much detail or recall distant events?	If so, it must be modified or generalised to make recall easier.
5	Is the question as specific as it can reasonably be?	If the item is too general, state it more specifically.
6	Is the item more specific than the way respondents think?	It should be expressed in more general terms.
7	Does the question overemphasise some condition?	It must be stated in less dramatic terms.
8	Are some of the words in the item ambiguous?	Reword it using more commonly recognised phrasing.
9	Is the question as free from threat to respondents as possible?	If not, change it to reduce the threat.
10	Does the question include only one issue?	If it is a double-barrelled item, it must be split or modified.
11	Will yea-sayers or nay-sayers always choose one answer?	If so, revise the item to include both 'yes' and 'no.'
12	Does the question lead respondents towards a particular answer?	If so, the leading phrase must be removed.
13	Is the question 'loaded' with a reason for responding in a particular way?	If so, the reason must be deleted.

9.7: The Questionnaire

The survey instrument used in this study, as shown in Appendix A, contains seven sections. The first section, labelled section A, requests some information about the company. Information such as the number of full-time employees, the average age of production equipment, the proportion of products made to stock, the dominant type of manufacturing process used in the plant, and the type of business strategy followed by the firm. In section B, the respondents were asked to indicate the extent of individual emphasis on a list of manufacturing improvement programmes in their firms. Section C asked the respondents to indicate the extent of their agreement with some statements which were designed to measure the involvement of manufacturing managers in setting the strategic direction of their firms. Similarly, section D was designed through some statements to measure the attitude of top managers towards manufacturing. Section E contained ten items which were designed to indicate the degree of how proactive a firm is, the level of co-ordination between manufacturing and other functions, and if manufacturing strategy is formally developed. The last two sections, namely, sections F and G were designed to measure the importance and performance of fifteen competitive capabilities.

9.8: Pilot Study

A pilot study was conducted in order to pretest the survey instrument. The piloting of surveys is an important and critical stage of questionnaire design. As Parasuraman (1986) put it

> 'even the most diligent questionnaire designer may make mistakes that can only be detected through an external evaluation' (p. 372).

An important issue in pilot studies is deciding the number of respondents in the pre-test sample. In this respect, Parasuraman (1986) again suggested that

> 'pre-test sample size is a subjective decision that depends on a variety of factors, such as how confident the researcher is that the questionnaire is sound and the time and money available. In general, however, it is better to pre-test the questionnaire systematically (i.e., by having specific objectives in mind and by extensive probing of respondents) on a relatively small sample than to pre-test it on a relatively large sample by simply asking the respondents to fill it out. In other words, the potential usefulness of pre-testing will depend more on quality than on quantity' (p. 373).

Thus the size of firms in the pilot study was kept small. That made it possible to carry out the pilot study in two stages. In the first stage, six manufacturing firms were visited. The manufacturing managers in these companies were interviewed in a free format mode to allow for the free exchange of ideas. These interviews helped in both highlighting important issues and refining the initial list of questions into a preliminary questionnaire.

The second stage of pilot study involved sending this preliminary questionnaire to fifteen companies in the manufacturing sector. A space was left at the end of each section of the questionnaire so that potential respondents could comment on the questions that they thought were unclear or difficult to answer. From the fifteen companies, eight responded with filling the questionnaire and making some comments. These comments were studied and if found suitable were incorporated into the survey instrument.

Piloting the questionnaire in a group of potential respondents will not uncover all the problems inherent in a questionnaire (Parasuraman, 1986). Some obvious errors might go undetected, especially with respect to questions that are ambiguous or have more than one meaning and thus can be interpreted differently by each respondent. As Hunt *et al.* (1982) noted

> 'a respondent may not realise that more than one meaning can be associated with a particular term. Because the error arises from different meanings being used by different respondents, a single respondent would be unlikely to bring this error to the attention of the interviewer' (p. 272).

To overcome this potential problem, all the items in the questionnaire were scrutinised. Moreover, the questionnaire was presented to some lecturers and post graduate colleagues at the Department of Manufacturing Engineering and Operations Management in the University who have experience in questionnaire design. They helped in identifying some trouble spots which might otherwise have gone unnoticed.

If modifications to the questionnaire are extensive, then additional pre-tests may be necessary (Parasuraman, 1986). Luckily, the changes made to the questionnaire in this research were minor, and therefore no additional pretesting of the questionnaire was carried out.

9.9: Mailing the Questionnaire

The questionnaire was mailed to 1257 manufacturing firms in late November 1995. Each questionnaire was accompanied by a cover letter which explained the purpose of the study. The cover letters were addressed to the manufacturing managers, and individually signed. A pre-paid return envelope was included with each questionnaire. After five weeks of the initial mailing, another wave of questionnaires was sent to all the firms which had not yet reply.

Out of the 1257 mailed questionnaires, 62 were returned by the Royal Mail undelivered. The reason was that the addressed firms had either moved to other places or were no longer in business. Thus the total sample was reduced to 1,195 firms.

From the two mailings, a total of 379 questionnaires was received which resulted in a response rate of 31.7 percent. However, there were 84 unusable questionnaires because the firms which received these questionnaires had a policy which prevents them from participating in surveys, the manufacturing manager is too busy to answer the questionnaire, manufacturing operations have been closed down, or the company has gone into receivership.

Therefore, the usable response was 295 from a total sample of 1111 firms which resulted in a net response rate of 26.6 percent.

9.10: Summary

Issues related to data collection were presented in this chapter. The survey methodology, based on questionnaires, was used because it is the best means for data collection where a limited amount of information is required from a large set of companies. Because of the low response rate usually associated with questionnaires, great care was taken in its design as discussed earlier in this chapter.

After getting the names and addresses from the FAME database, the questionnaires were mailed to manufacturing managers in three industrial sectors. Clear instructions were given on how to complete the questionnaire, and a pre-paid addressed envelope was included for the convenience of the potential respondents.

A pilot study was conducted, in two stages, to pretest the survey instrument. In the first stage, six manufacturing firms were visited and interviewed, and the views and comments of the manufacturing managers in these firms were solicited. The second stage of pilot study involved sending the questionnaire, after incorporating some changes from the first stage, to fifteen companies in the manufacturing sector.

The final version of the questionnaire was mailed to 1257 manufacturing firms in late November 1995. Another wave of questionnaires was sent, after five weeks of the initial mailing, to all the firms that had not sent back the questionnaire. After excluding returned questionnaires which were not completed, a response rate of 26.6 percent was achieved.

In the next chapter of this thesis, the focus will be on exploring the data that was obtained through the questionnaire.

Chapter 10:

Exploratory Data Analysis

10.1: Overview

10.2: Nonresponse Bias

10.2.1: Respondents vs. Nonrespondents

10.2.2: Early vs. Late Respondents

10.3: Checking for Multivariate Outliers

10.4: General Characteristics of the Sample

10.5: Summary

10.1: Overview

Exploratory data analysis is an important phase in the research process. It involves thorough examination of the data. This exercise as Hair, Jr. *et al.* (1995) noted is a

> 'time-consuming, but necessary step that is sometimes overlooked by data analysts. Careful analysis of data leads to better prediction and more accurate assessment of dimensionality' (p. 33).

There are numerous tests that can be applied for data exploration depending on the type of multivariate techniques that are to be used for testing the hypotheses. For this research, three types of data exploration are employed. The first type is checking for nonresponse bias, that is examining the data to see if the sample is a good representation of the population under study. The second type is checking for multivariate outliers. These are cases with extreme values which can adversely affect the results of hypotheses testing. The last type of data exploration is investigating the general characteristics of the sample. These three data analyses are presented below.

10.2: Nonresponse Bias

The degree of sample representativeness of the entire population is examined using two methods. The first method is the direct comparison of respondents and nonrespondents in some variables. For this research, the variables that are used are number of employees, type of industry, and some financial variables which are obtained from the FAME database. The second method for checking for nonresponse is an indirect one. It was proposed by Armstrong and Overton (1977) who suggested that the characteristics of late respondents can be used as surrogate measures for the attributes of nonrespondents.

10.2.1: Respondents vs. Nonrespondents

Table 10.1 below shows the comparison between respondents and nonrespondents in terms of the number of employees and some profitability ratios. These financial attributes are profit margin, return on capital employed, return on shareholders funds, return on total assets, and turnover.

Table 10.1
Comparison of Respondents and Nonrespondents

Variable	Respondents Mean	Respondents Std. Dev.	Nonrespondents Mean	Nonrespondents Std. Dev.	t - value	p - value
Number of Employees	572.0	1426.	560.1	2232.	0.09	.93
Profit Margin	11.47	104.9	3.86	28.05	1.23	.22
Return on Shareholders Funds	23.33	92.94	57.24	780.9	-0.74	.46
Return on Total Assets	6.84	23.10	5.42	17.96	1.10	.27
Return on Capital Employed	14.34	75.66	34.21	469.6	-0.72	.47
Sales Turnover (In Millions of Pounds)	68.82	343.7	46.95	187.9	1.05	.30

Each one of these ratios is measured in percentages. By using the t-tests, all of the attributes indicate that the differences between respondents and nonrespondents are not significant. Next, respondents and nonrespondents are compared with respect to the type of industry as shown in Table 10.2.

Table 10.2
Comparison of Respondents and Nonrespondents With Respect to Type of Industry

Industry type	Respondents	Nonrespondents
Mechanical equipment (SIC-32)	148	497
Electrical equipment (SIC-34)	101	351
Motor vehicles (SIC-35)	46	114

Chi-square = 2.9
Degrees of Freedom = 2
Significance (p) = 0.235

The chi-square value of 2.9 with two degrees of freedom and a probability value of 0.235 indicates that the differences between the two groups are not significant. Thus, the conclusion from the statistical test carried out is that there is no nonresponse bias.

10.2.2: Early vs. Late Respondents

In order to ascertain the findings that the differences between respondents and nonrespondents are insignificant, early and late respondents are compared using primary data that are collected by the survey instrument.

The variables used are the age of equipment, type of business strategy followed, and type of process used. Table 10.3 shows the chi-square values, degrees of freedom, and significance levels.

Table 10.3
Comparison of Early and Late Respondents

Variable	Chi-Square	Degrees of Freedom	Significance
Age of equipment	0.71	3	0.871
Type of strategy followed	1.113	3	0.770
Type of process used	0.27	3	0.966

The values that are shown in the table for the significance levels are very high. These results point to the conclusion that there is no difference between late and early respondents, and therefore there is no difference in these variables between respondents and nonrespondents. The results hence support the earlier finding that there is no nonresponse bias.

10.3: Checking for Multivariate Outliers

Outliers are cases with extreme values that can have negative effects on the results inferred from hypotheses testing. Such cases have 'unique combination of characteristics identifiable as distinctly different from the other observations' (Hair *et al.*, 1995). Because of their negative impact on statistical tests, they are usually isolated and eliminated from the rest of the representative cases.

Multivariate outliers are different from univariate or bivariate outliers in the sense that more than two variables are considered for their detection. Their detection is usually arrived at by using the Mahalanobis distance measure. This measure is the distance in multidimensional space between each case and the mean of all cases. The longer the distance between a case and the mean of cases, the more likely that this case is an outlier. By using the chi-square statistic, a threshold value for signicance level of .001 is taken as a designation for an outlier.

The tables that show the cases, their Mahalanobis distance, and siginificance levels are grouped in Appendix B. From these tables, it is apparent that all cases except one have a significance level above .001, with the one exception having a value of .0009 which is very close to the threshold value.

Thus, it can be concluded from this test that there are no explicit outliers in the sample of firms under study.

10.4: General Characteristics of the Sample

Table 10.4 shows some general characteristics of the sample. The first item on the table presents the sizes of the firms that responded to the questionnaire in terms of the number of employees.

Around 50 percent of these companies have two hundred or less employees and more than 83 percent have less than five hundred employees. That means most of the firms in the sample are small to medium in size. Three industrial sectors were sampled, and the representation of each industry in the sample is similar to the make up of the population.

Around 12.5 percent of the firms in the sample have process technologies that are less than five years old. That means the majority of the firms in the sample do not have the latest technology for their particular manufacturing processes.

The dominant type of manufacturing process used is batch and, as might be expected, the majority of firms are competing on both cost and differentiating their products through other means.

Table 10.4
General Characteristics of the Sample

	Frequency	Percent
Size of Firm		
Less than 200 employees	147	49.9
Between 200 and 500 employees	98	33.2
More than 500 employees	50	16.9
Industry Type		
Mechanical equipment (SIC-32)	148	50.2
Electrical equipment (SIC-34)	101	34.2
Motor vehicles (SIC-35)	46	15.6
Average Age of Equipment		
Less than 5 years old	37	12.5
5 to 15 years old	205	69.5
15 to 30 years old	51	17.3
Older than 30 years	2	.7
Type of Process Used		
Job shop	55	18.6
Batch	148	50.2
Assembly line	69	23.4
Continuous flow	23	7.8
Business Strategy		
Cost leadership	53	18.0
Differentiation	52	17.6
Both cost and differentiation	181	61.4
No particular strategy followed	9	3.1

With respect to products made to stock, Table 10.5 indicates that more than half of the firms in the sample stock only around 10 percent of their products, and the rest is made to order. This observation falls in line with the fact that the dominant production process in the sampled firms is batch.

Table 10.5
The Percentages of Products Made to Stock

Percentage Interval	Frequency	Percent	Cumulative percent
0 - 10	163	55.3	55.3
11 - 20	29	9.9	65.2
21 - 30	12	4.0	69.2
31 - 40	6	2.0	71.2
41 - 50	12	4.0	75.2
51 - 60	13	4.4	79.6
61 - 70	11	3.8	83.4
71 - 80	16	5.4	88.8
81 - 90	7	2.4	91.2
91 - 100	26	8.8	100.0

The next two tables present secondary data which are obtained from the FAME financial database. Table 10.6 shows some profitability indicators of the sample. The standard deviations demonstrate the wide variability of these indicators. That means there are quite a lot of differences between firms in the sample in terms of their success in the marketplace.

Table 10.6
Profitability Indicators of the Sample

Indicator	Mean	Std Dev.
Return on total assets (%)	6.84	23.10
Profit margin (%)	11.47	104.94
Return on capital employed (%)	14.34	75.66
Return on shareholders funds (%)	23.33	92.94
Sales turnover (in millions of pounds)	68.9	343.8

The distribution of sales turnover is shown in Table 10.7. More than 83 percent of the firms in the sample have a turnover of 50 million pounds or less. These data lend further support to the earlier finding that most of the firms are small to medium enterprises.

Table 10.7
Sales Turnover in millions

Sales Interval	Frequency	Percent
Less than 10 M	82	27.8
Between 10 and 50 M	164	55.6
Between 50 and 100 M	24	8.1
Between 100 and 500 M	19	6.4
Between 500 and 1000 M	3	1.0
More than 1000 M	3	1.0

10.5: Summary

An important first step in data analysis is understanding the data through exploratory data analysis (Tukey, 1977). Three types of data exploration are carried out. The first type of data exploration is the examination for nonresponse bias. The comparisons between respondents and nonrespondents, and between early and late respondents indicate that there is no nonresponse bias. Thus the sample is a fair representation of the population. That means the results from the analysis of the sample can be generalised to the entire population under study.

The second type of data exploration is checking for multivariate outliers. These are cases with extreme values that can have negative outcome on the results inferred from hypotheses testing. The analysis using Mahalanobis distance and a significance level of .001 indicated that are no cases in the sample which can be considered as outliers.

The third type is sample description. From this analysis, it is concluded that most of the firms are either small or medium in size, and use batch processes. It is also found that there are large differences between the firms in the sample with respect to how profitable they are in the marketplace.

After obtaining these satisfactory results from the exploratory data analysis phase, the next step in this research will focus on purifying the measures of the dimensions of the strategic manufacturing effectiveness framework, which is the subject of the next chapter.

Chapter 11:

Measure Purification and Assessment

11.1: Overview

The objective of this chapter is to purify the seven latent variables that measure strategic manufacturing effectiveness and its causes and outcomes.

As explained in chapter seven, when discussing the steps of Churchill's (1979) paradigm for developing instruments, purification of measures involves the assessment of reliability, unidimensionality, discriminant validity, and convergent validity. Each of these assessments is conducted in turn beginning with the next section.

It was pointed out also in chapter seven that structural equation modelling technique (SEM) is used for these assessments. There are many packages that are designed to perform SEM. Some of these are EQS, Liscomp, Calis, Amos and Sepath. However LISREL is the first programme developed and has been widely used in many disciplines. Its implementation in a wide variety of research settings has been very well documented in the academic literature. Many books have also been written which explain how to use this specific programme. Thus, LISREL is used in this research.

It is worth pointing out that even though all of the above mentioned programmes often produce comparable results, they do not usually function in the same way, especially with respect to how they handle input data files that are to be analysed.

SEM technique generally deals with two models; a measurement model and a structural equation model (Gregson, 1992). The measurement model is concerned with how the latent variables are measured by the observed variables, and the structural equation model describes the causal relation among the latent variables (Hayduk, 1987). The LISREL programme estimates two equations for the measurement model and one for the structural model. These equations are shown in Appendix C.

Anderson and Gerbing (1988) recommended using a two step approach when developing and purifying measures. This approach is adopted for this research. Step one calls for purifying the measures of each latent variable individually. It is conducted by exposing the measurement model of each latent variable to the various reliability and validity tests. Step two of Anderson and Gerbing's approach is used to examine the full model which encompasses all the latent variables in a theoretical network. The emphasis here is to validate the measurement models of the latent variables and to investigate the interaction between the latent variables. This investigation is conducted by examining both the measurement and structural models. This two-step approach has been widely used in many journal papers and doctoral theses, each one applying it with different structure and amount of detail.

As opposed to the two-step approach, the other choice is to use a one step approach to estimate both the measurement and structural models simultaneously. However, the advantages of the two-step approach can be summarised as follows:

> 'First, it allows tests of the significance for all pattern coefficients. Second, the two-step approach allows an assessment of whether any structural model would give acceptable fit. Third, one can make an asymptotically

independent test of the substantive or theoretical model of interest' (Anderson and Gerbing, 1988, p. 422).

The implementation of the two-step approach that is followed in this research is based on the methodology of Gray (1994) who provided extensive details for each step in a systematic way.

Step one of Anderson and Gerbing's approach is implemented in the next three sections which deal with the assessment of reliability, unidimensionality and convergent validity, and discriminant validity respectively. Afterwards, for step two, the full model is examined.

In testing the reliability and validity of the measures in the following sections, comprehensive details of analyses are presented for each step. This is important as Flynn *et al.* (1994) stated:

> 'publication of complete instruments and their measurement analysis allows other researchers to use the same instruments with different populations, permitting development of the body of knowledge about a particular field' (p. 349).

11.2: Internal Consistency Reliability

The internal consistency reliability assessment provides information about the presence (or absence) of random errors in the measures. Using an unreliable measure is analogous to using an elastic ruler, each time it is used it will give different results. Because of the significance of developing reliable measures, many assessments were proposed to test reliability. The LISREL programme provides information that can be used to calculate three reliability tests. They are indicator reliability, composite reliability and shared variance.

Indicator reliability of each observed variable is defined as the squared correlation between the indicator and the latent variable it is supposed to measure. It can be represented mathematically as:

$$\text{Indicator Reliability} = \lambda^2 / (\lambda^2 + \delta)$$

where λ is the standardised loading for the item, and δ represents its measurement error.

As with all other measures of reliability, there is no particular cut-off value that can be considered as the difference between a reliable and unreliable indicator. Thus rules of thumb are used which are based on previous research. With respect to indicator reliability, values that are greater than .50 are assumed acceptable (Fornell and Larcker, 1981). That means less than 50% of the observed variable's variance is due to error.

Composite reliability of n indicators of a latent variable is defined by Werts *et al.* (1974) as follows:

$$\text{Composite Reliability} = (\Sigma\lambda)^2 / ((\Sigma\lambda)^2 + \Sigma\delta)$$

The values of composite reliability 'represent the ratio of the trait variance to the sum of the trait and error variance' (Venkatraman, 1989). That means the greater the value of composite reliability the better the reliability of the measure. The rule of thumb here is that a value of .70 is considered minimally acceptable (Hair *et al.*, 1995; Nunnally, 1978), even though other researchers like Bagozzi and Yi

(1988) indicated that values greater than .60 are acceptable, especially for newly formed measures.

Shared variance calculates how much of the observed variables' variances are explained by the latent variable. Its definition is:

$$\text{Shared Variance} = \Sigma\lambda^2 / (\Sigma\lambda^2 + \Sigma\delta)$$

Fornell and Larcker (1981) recommended that a value of .5 or greater be accepted.

Along with these three measures of assessing reliability, three more tests are utilised which are generated from the statistical programme, SPSS. The first one, and most widely used, is Cronbach's coefficient alpha. This measure is analogous to the composite reliability measure that is calculated from LISREL output, and thus the same rule of thumb is applied with respect to the range of accepted values.

The second test calculates the value of coefficient alpha if an item is deleted. If the value of alpha increases considerably, then that indicates deletion of that item is preferable.

The final test determines the correlation between each item and the whole set of items in a latent variable. Churchill (1979) pointed out that items with low correlation values should be eliminated.

The reliability tests are now applied to the seven latent variables, starting with strategic manufacturing effectiveness.

11.2.1: Strategic Manufacturing Effectiveness

Strategic manufacturing effectiveness is measured by twenty two manufacturing improvement programmes as pointed out in chapter eight. The use of such a large number of manufacturing improvement programmes helps in covering the domain of the strategic decision categories as stipulated by Hayes and Wheelwright (1984) and other researchers (see Table 3.2 in chapter three). However, researchers such as Bentler and Chou (1987) recommend that when developing models, the number of observed variables, in the model as a whole, should not go far beyond twenty variables. Otherwise, the interpretation of the results becomes unwieldy.

A common solution for reducing large number of variables is to combine similar items. The advantages of combining items extend beyond the simplification of the results' interpretation process. As noted by Churchill (1979), when summated items are used, the specificity of items is averaged out and the combined items tend to decrease measurement error and thus increase reliability.

Therefore, before reliability tests are applied to this latent variable, the number of items is reduced. Anderson and Gerbing (1988) suggested that the statistical method most suitable for data reduction is factor analysis which, as its name implies, attempt to find a smaller number of factors that are measured by similar variables. These factors are then used as substitutes for the original variables in subsequent analyses. Hair et al (1995) noted that there are three strategies for selecting surrogate variables for the identified factors depending on the objectives of the researcher. One strategy is to use just one variable that has the highest factor loading as the measure of each factor. The second strategy is to use factor scores. These are composite measures that utilise the original raw data and factor analytic results. However, Hair *et al.* (1995) recommended that if the objective of the research is generalisability of the results to other samples, then summated scales should be used. For summated scales,

> 'all the variables loading highly on a factor would be totalled. The total, or its average, could then be the surrogate variable. The objective, just as in the case of selecting a single variable, is to best represent the basic nature of the factor or component' (Hair *et al.*, 1995, p. 390)

This research therefore utilises summated scales for the reduction of the variables in this latent variable. By using the 'principal components' method with 'varimax' rotation in exploratory factor analysis under SPSS, the results, shown in Table 11.1, indicate that manufacturing strategic improvement programmes group into seven factors.

The high factor loadings (greater than .50) support this classification. Even though the values of coefficient alpha for two factors (process technology and capacity upgrade) are below the minimum recommended level of .60, they were left in the analysis pending the application of reliability tests that relate these factors to strategic manufacturing effectiveness. Moreover, these results are in agreement with the factors that Roth and Miller (1990) found when they conducted similar work using the same manufacturing improvement programmes. The last factor comprises only one manufacturing choice. Thus, its factor loading cannot be computed.

Table 11.1
Factors of Manufacturing Improvement Programmes

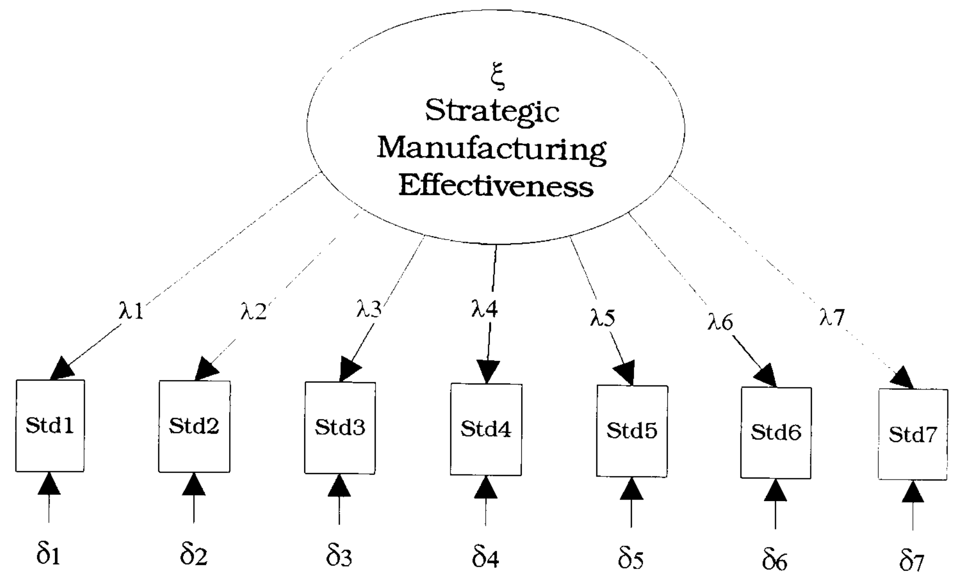
			Loadings
	Materials Flow-JIT	(.63)*	
Str1	Manufacturing lead time reduction		.86
Str2	Just-in-Time (JIT)		.86
	Process Technology	(.47)	
Str3	Introduction of Flexible manufacturing systems		.71
Str4	introduction of CAD/CAM		.50
Str5	Developing new processes for new products		.77
Str6	Developing new processes for old products		.51
	Capacity Upgrade	(.48)	
Str7	Capacity expansion		.81
Str8	Reconditioning of physical facilities		.81
	Resources Improvements	(.76)	
Str11	Management training		.85
Str12	Worker training		.87
Str13	Worker safety		.73
	Quality Programmes	(.74)	
Str15	Statistical quality control		.71
Str16	Vendor quality		.66
Str17	Zero defects		.76
Str18	Quality circles		.64
Str19	Preventive maintenance		.71
	Information Systems	(.81)	
Str20	Integrating Systems Across Areas		.92
Str21	Integrating Systems Within Manufacturing		.92
	New Production Introduction	(-)	
Str22	Improving new product introduction capability		-

* Inter-item reliability as measured by Cronbach's coefficient Alpha

So the seven factors are used in place of the original variables. The value of each factor is the average of the manufacturing improvement programmes that it constitutes.

Turning now to the application of reliability tests, the measurement model for strategic manufacturing effectiveness is depicted in Figure 11.1 which shows that this construct is defined by the new variables Std1 - Std7. The $\lambda_1 - \lambda_7$ parameters are the loadings of each variable on the construct. Errors in the measurement of each variable are represented by the symbols $\delta_1 - \delta_7$. This convention of model notation is used for subsequent analyses of the other latent variables.

Figure 11.1
Measurement model for strategic manufacturing effectiveness



Std1. Materials Flow-JIT
Std2. Process Technology
Std3. Capacity Upgrade
Std4. Resources Improvements
Std5. Quality Programmes
Std6. Information Systems
Std7. New Product Introduction

Table 11.2 presents the data pertaining to these reliability tests. The results from LISREL were obtained using the 'maximum likelihood' estimation method with covariance matrix. This method was used for all other analyses that were generated from LISREL. After inspecting the reliability of each indicator, it is observed that Std3 shows poor indicator reliability and its item-to-total correlation indicates that it does not correlate highly with the rest of the items. The values of composite reliability and coefficient alpha are satisfactory, however, the shared variance value of .3450 suggests that only about 35% of the variance is accounted for by strategic manufacturing effectiveness.

The rest of the variance is due to measurement error. Consequently in order to improve the shared variance, item Std3 that has poor reliability is eliminated.

The results of reliability tests of the revised model of strategic manufacturing effectiveness are shown in Table 11.3. There are no significant changes in the values of the composite reliability, coefficient alpha, and the shared variance. The value of the shared variance is still below the recommended level of .50. However it can be observed from the column that shows the values of alpha if an item is deleted that there are no further items as candidates for deletion.

Table 11.2
Reliability estimates for the measures of strategic manufacturing effectiveness

Item	**Indicator reliability**	**Item-to-total correlations**	**Alpha if item is deleted**
Std1	.3364	.4657	.6832
Std2	.3481	.5051	.6774
Std3	.0576	.1930	.7487
Std4	.4225	.5319	.6727
Std5	.5041	.5722	.6601
Std6	.2401	.4229	.6939
Std7	.2401	.4339	.6959
Composite reliability		.7751	
Shared variance		.3450	
Coefficient alpha		.7232	

Item Std3 which stands for capacity upgrade was deleted because of its poor reliability, however from the substantive point of view, this deletion can be interpreted as that the respondents of the questionnaire do not consider capacity expansion as a factor that represents manufacturing effectiveness.

Table 11.3
Reliability estimates for the measures of strategic manufacturing effectiveness- Revised set

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Std1	.3481	.5011	.7088
Std2	.3600	.5231	.7057
Std4	.4225	.5222	.7067
Std5	.4900	.5610	.6942
Std6	.2401	.4359	.7269
Std7	.2401	.4368	.7369
Composite reliability		.7606	
Shared variance		.3501	
Coefficient alpha		.7487	

Thus the internal consistency reliability tests provide some evidence for the six-indicator model of strategic manufacturing effectiveness. These six indicators are:

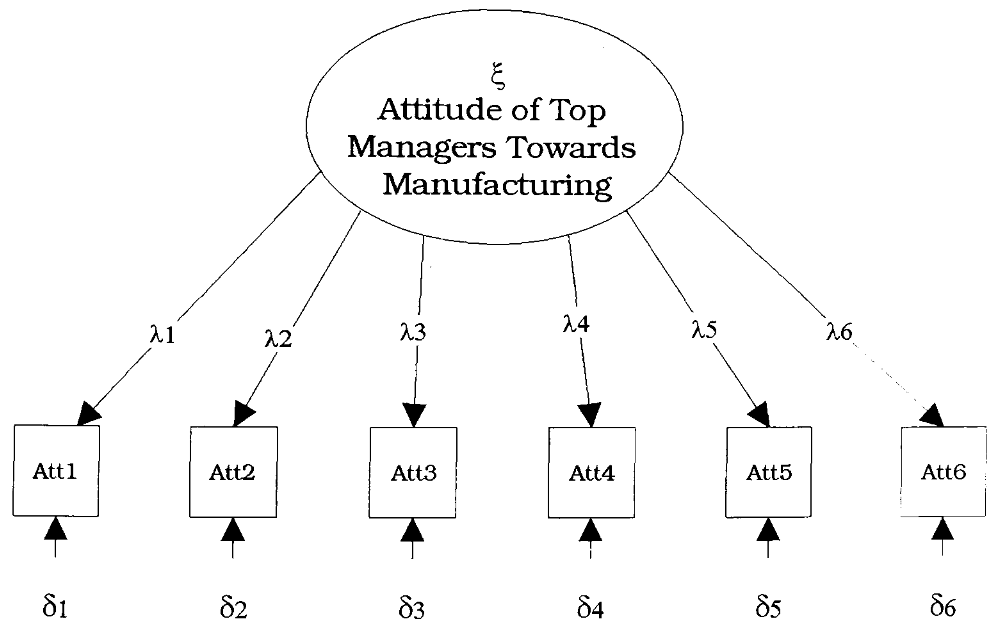
Std1 Materials Flow-JIT
Std2 Process Technology
Std4 Resources Improvements
Std5 Quality Programmes
Std6 Information Systems
Std7 New Product Introduction

11.2.2: The Attitude of Top Managers

The measurement model for the latent variable of the attitude of top managers towards manufacturing is depicted in Figure 11.2 which shows that this latent variable is defined by the observed variables Att1 - Att6.

Table 11.4 presents the data pertaining to the reliability tests. After inspecting the reliability of each indicator, it is observed that items Att3 and Att5 show poor reliability. The item-to-total correlations of these items also indicate that they do not correlate highly with the rest of the items. As for item Att4, it has a low reliability value, however its item-to-total correlation is acceptable. So it is kept with the other items pending more tests. The values of composite reliability and coefficient alpha for this model are satisfactory, however, the shared variance value of .2877 suggests that only about 29% of the variance is accounted for by the latent variable. The rest of the variance is due to measurement error. Thus in order to improve the shared variance. the items that have both poor reliability and low item-to-total correlation are eliminated.

Figure 11.2
Measurement model for the attitude of top managers towards manufacturing



Att1. Top managers consider manufacturing to be neutral and incapable of influencing competitive success.
Att2. They minimise their involvement with, and thus their perceived dependence on, manufacturing.
Att3. They encourage manufacturing to follow industry practice in matters regarding the work force, equipment purchases, and capacity additions.
Att4. They view economies of scale related to the production rate as the most important source of manufacturing efficiency.
Att5. They regard resource allocation decisions as the most effective means of addressing major strategic issues in manufacturing.
Att6. They communicate frequently with the manufacturing managers to understand the problems facing manufacturing and help to solve them.

Table 11.4
Reliability estimates for the measures of the attitude of top managers towards manufacturing

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Att1	.3969	.4562	.6090
Att2	.6241	.5686	.5644
Att3	.0225	.1638	.7010
Att4	.2304	.4879	.5990
Att5	.1024	.3213	.6542
Att6	.3481	.4153	.6255
Composite reliability		.6723	
Shared variance		.2877	
Coefficient alpha		.6711	

Preliminary results from the reliability tests of the measurement model of this latent variable after deleting items Att3 and Att5 indicated that item Att4 should be deleted also because of its low indicator reliability and item-to-total correlation. The results of the revised model after this deletion are shown in Table 11.5

Table 11.5
Reliability estimates for the measures of the attitude of top managers towards manufacturing- Revised set

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Att1	.4096	.5166	.6455
Att2	.6400	.5955	.5484
Att6	.3481	.4933	.6784
Composite reliability		.7216	
Shared variance		.4678	
Coefficient alpha		.7144	

As shown in Table 11.5, there is an improvement in the values of both the composite reliability and coefficient alpha. However, more significant improvement is observed in the value of the shared variance, which climbs close to .47.

So the internal consistency reliability tests provide adequate evidence for the three-indicator model of the attitude of top managers towards manufacturing. These three indicators are:

Att1	Top managers consider manufacturing to be neutral and incapable of influencing competitive success.
Att2	They minimise their involvement with, and thus their perceived dependence on, manufacturing.
Att6	They communicate frequently with the manufacturing managers to understand the problems facing manufacturing and help to solve them.

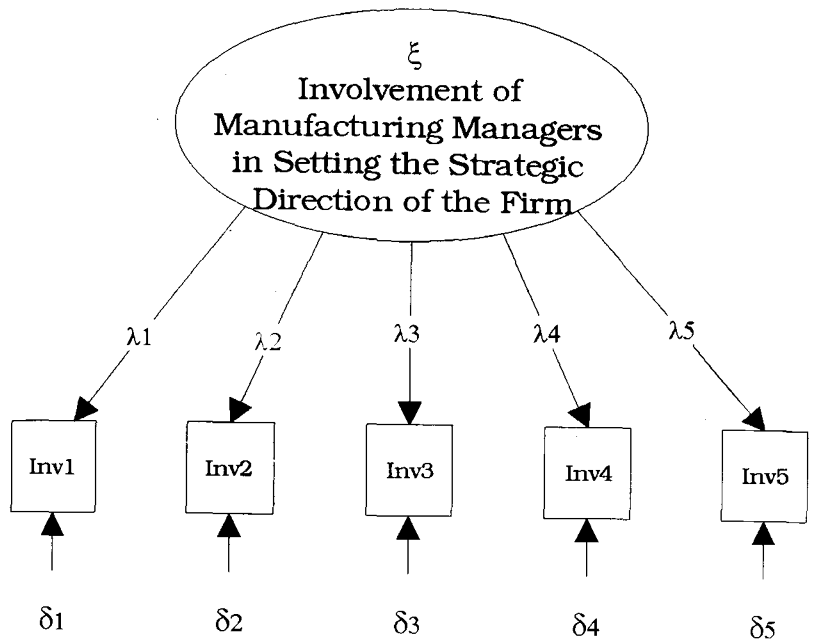
11.2.3: The Involvement of Manufacturing Managers

The measurement model for the latent variable that is designated 'the involvement of manufacturing managers in setting the strategic direction of the firm' is depicted in Figure 11.3 which shows that this latent variable is defined by the observed variables Inv1 - Inv5.

Table 11.6 presents the data pertaining to the reliability tests for this latent variable. After examining the reliability of each indicator, it is observed that item Inv5 shows lower indicator reliability compared with the other items, even though its item-to-total correlation is minimally acceptable.

The values of composite reliability and coefficient alpha for this model are good, however, the shared variance value of .3793 suggests that only 38% of the variance is accounted for by the latent variable. The rest of the variance is due to measurement error. Thus in order to improve the shared variance, item Inv5 is eliminated.

Figure 11.3
Measurement model for the involvement of manufacturing managers in setting the strategic direction of the firm



Inv1. Manufacturing managers seek to understand their company's business strategy and the kind of competitive advantage it is pursuing.
Inv2. Manufacturing managers view their roles as being reactive.
Inv3. Manufacturing managers involve very late in corporate policy debates.
Inv4. Manufacturing managers do not express themselves well in corporate policy debates.
Inv5. Manufacturing managers spend most of their time in dealing with day-to-day operating issues.

Table 11.6
Reliability estimates for the measures of the involvement of manufacturing managers in setting the strategic direction of the firm

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Inv1	.2704	.4494	.7180
Inv2	.3481	.5101	.6958
Inv3	.5476	.5973	.6584
Inv4	.5041	.5848	.6640
Inv5	.2304	.4061	.7357
Composite reliability		.7482	
Shared variance		.3793	
Coefficient alpha		.7416	

The results of the revised model are shown in Table 11.7. There is a slight drop in the values of both the composite reliability and coefficient alpha. However, more significant improvement is observed in the value of the shared variance.

Table 11.7
Reliability estimates for the measures of the involvement of manufacturing managers in setting the strategic direction of the firm- Revised set

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Inv1	.2916	.4746	.7082
Inv2	.3600	.5178	.6824
Inv3	.5329	.5798	.6463
Inv4	.4900	.5614	.6566
Composite reliability		.7392	
Shared variance		.4182	
Coefficient alpha		.7357	

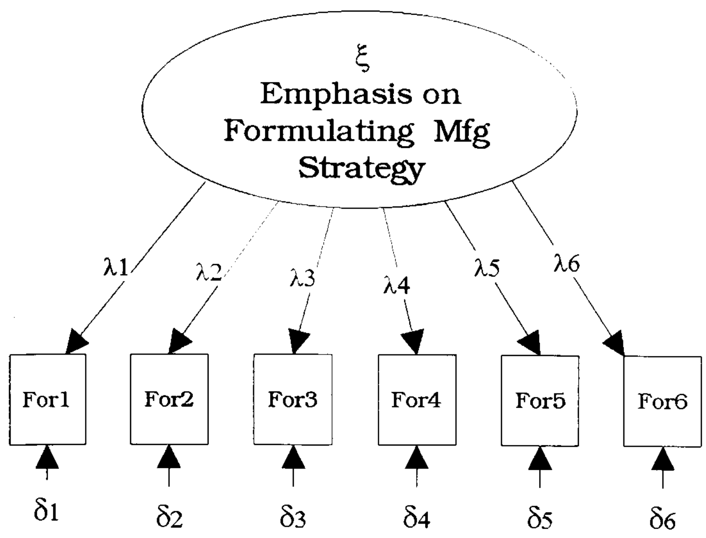
Therefore, the internal consistency reliability tests provide some evidence for the four-indicator model measuring the involvement of manufacturing managers in setting the strategic direction of the firm. These four indicators are:

Inv1 Manufacturing managers seek to understand their company's business strategy and the kind of competitive advantage it is pursuing.
Inv2 Manufacturing managers view their roles as being reactive.
Inv3 Manufacturing managers involve very late in corporate policy debates.
Inv4 Manufacturing managers do not express themselves well in corporate policy debates.

11.2.4: Formulating Manufacturing Strategy

The measurement model for this latent variable is depicted in Figure 11.4 which shows that this latent variable is defined by the observed variables For1 - For6. The results of the reliability tests are presented in Table 11.8.

Figure 11.4
Measurement model for the emphasis on formulating manufacturing strategy



For1. Manufacturing strategy is formally formulated.
For2. Strategic issues involving manufacturing are tackled by outside experts.
For3. Develop thorough analysis when confronted with a major decision.
For4. Screen decisions to be sure they are consistent with competitive strategy.
For5. Employ detailed measurements and controls of operating performance.
For6. Incorporate nonfinancial considerations in the capital budgeting process.

Table 11.8
Reliability estimates for the measures of formulating manufacturing strategy

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
For1	.4761	.3397	.3784
For2	.0001	-.2890	.7110
For3	.4356	.5030	.2878
For4	.3136	.3624	.3665
For5	.2916	.4370	.3122
For6	.1849	.3443	.3717
Composite reliability		.6017	
Shared variance		.2728	
Coefficient alpha		.4769	

The indicator reliability and item-to-total correlation of items For2 and For6 are poor. The shared variance which is .2728 is below the recommended level. So in order to increase the reliability of this latent variable, both items For2 and For6 are eliminated from further analysis.

The results of the revised model are shown in Table 11.9. Examination of the alpha, composite and indicator reliabilities reveals that they have improved significantly. There is also a notable improvement in the shared variance.

Table 11.9
Reliability estimates for the measures of formulating manufacturing strategy- Revised set

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
For1	.3844	.5099	.6162
For3	.5476	.5740	.5762
For4	.3025	.4351	.6618
For5	.2809	.4188	.6767
Composite reliability		.7059	
Shared variance		.3793	
Coefficient alpha		.6976	

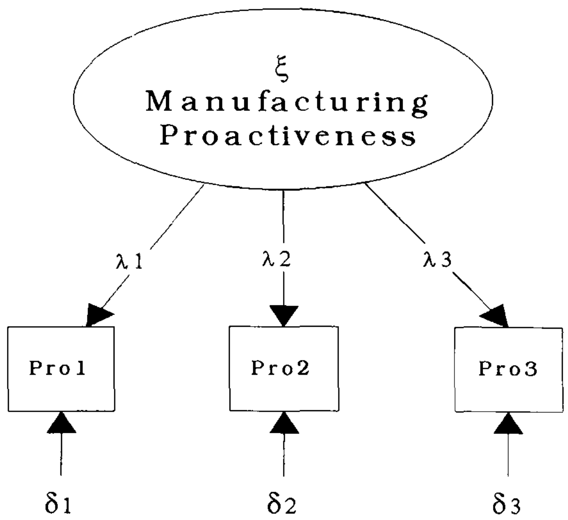
Thus the internal consistency reliability tests, taken together, provide some evidence for the four-indicator model of formulating manufacturing strategy. These indicators are:

For1 Manufacturing strategy is formally formulated
For3 Develop thorough analysis when confronted with a major decision.
For4 Screen decisions to be sure they are consistent with competitive strategy.
For5 Employ detailed measurements and controls of operating performance.

11.2.5: Manufacturing Proactiveness

The measurement model for manufacturing proactiveness is depicted in Figure 11.5 which shows that this latent variable is defined by the observed variables Pro1 - Pro3.

Figure 11.5
Measurement model for proactiveness



Pro1. Constantly seek new opportunities related to the present operations.
Pro2. Operations can be generally characterised as high-risk.
Pro3. Anticipate the potential of new manufacturing practices and technologies and seek to acquire expertise in them long before their implications are fully apparent.

Table 11.10 shows the data of the reliability tests. After examining the reliability of each indicator, it is observed that item Pro3 exhibits both lower indicator reliability and item-to-total correlation compared with other items. The values of composite reliability and coefficient alpha for this model are marginally adequate, however, the shared variance value of .3136 suggest that only 31% of the variance is accounted for by the latent variable. The rest of the variance is due to measurement error.

In order to see if the model will improve if item Pro3 is eliminated, the reliability measures of a revised model are calculated. These measures show that there is a drop in the values of the composite reliability, coefficient alpha, and the indicator reliability of item Pro2. On the other hand the indicator reliability of item Pro1 and shared variance increased slightly. Because of the negligible improvement for the revised model, item Pro3 was kept alongside the other two items.

Table 11.10
Reliability estimates for the measures of manufacturing proactiveness

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Pro1	.4096	.4104	.4019
Pro2	.2916	.3679	.4701
Pro3	.2401	.3545	.5123
Composite reliability		.5752	
Shared variance		.3136	
Coefficient alpha		.5593	

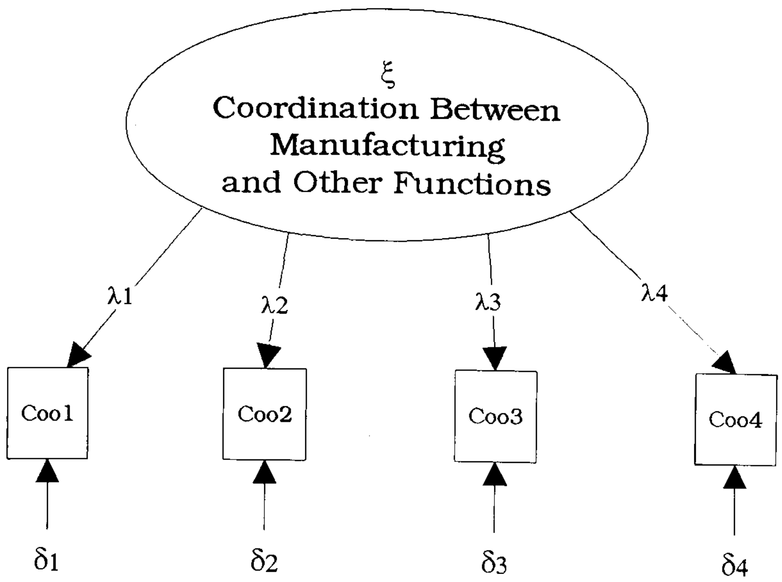
Therefore, the internal consistency reliability tests provide some evidence for the three indicator model of manufacturing proactiveness, which are:

Pro1 Constantly seek new opportunities related to the present operations.
Pro2 Operations can be generally characterised as high-risk.
Pro3 Anticipate the potential of new manufacturing practices and technologies and seek to acquire expertise in them.

11.2.6: Co-ordination with Other Functions

The measurement model for this latent variable is depicted in Figure 11.6 which shows that this latent variable is defined by the observed variables Coo1 - Coo4. Table 11.11 presents the data of the reliability tests. The indicator reliability of item Coo4 and its item-to-total correlation is lower than the other items. If this item is deleted, then alpha will increase from .7625 to .8116.

Figure 11.6
Measurement model for the co-ordination between manufacturing and other functions



Coo1. Interactive development of business, manufacturing, and other functional strategies.
Coo2. Extensive interactions between manufacturing and other functions to facilitate product design, field service, and sales training.
Coo3. Transfer of 'know-how' between functions.
Coo4. Help suppliers to solve problems.

Table 11.11
Reliability estimates for the measures of the co-ordination between manufacturing and other functions

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Coo1	.4761	.5721	.7004
Coo2	.7056	.6670	.6455
Coo3	.6241	.6773	.6492
Coo4	.1600	.3628	.8116
Composite reliability		.7830	
Shared variance		.4895	
Coefficient alpha		.7625	

The results after deleting item Coo4 are shown in Table 11.12. Shared variance at .5671 is above the recommended minimum. Indicator reliabilities, composite reliability and alpha all show satisfactory results.

Table 11.12
Reliability estimates for the measures of the co-ordination between manufacturing and other functions- Revised set

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Coo1	.4225	.6148	.7899
Coo2	.6241	.7145	.6847
Coo3	.6561	.6622	.7442
Composite reliability		.7957	
Shared variance		.5671	
Coefficient alpha		.8116	

Therefore, the internal consistency reliability tests provide strong evidence for the three-indicator model of co-ordination between manufacturing and other functions. These indicators are:

Coo1 Interactive development of business, manufacturing, and other functional strategies.
Coo2 Extensive interactions between manufacturing and other functions to facilitate product design, field service, and sales training.
Coo3 Transfer of 'know-how' between functions.

11.2.7: Manufacturing Competence

Manufacturing competence is hypothesised to be measured by fifteen competitive capabilities. Following Kim and Arnold (1993), the competence in each competitive capability is calculated as the product of the importance of the capability and the strength in that capability. Both importance and strength were measured by five-point scales.

As discussed in section 11.2.1 with respect to strategic manufacturing effectiveness, the number of competitive capabilities, being too high, needs to be reduced through summing items which are similar. The same procedure used in that section is applied here also.

Table 11.13 presents the results of factor analysis which indicate that there are five factors that group the fifteen capabilities. The factor loadings and the values of coefficient alpha provide strong support for these factors.

Table 11.13
Factors of Manufacturing Competitive Capabilities

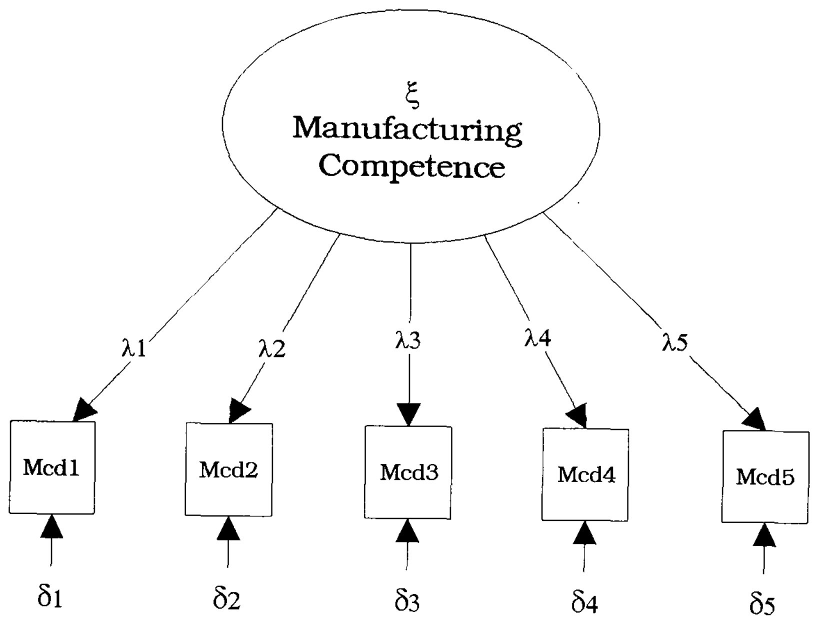
		Reliability	Loadings
	Cost [(1)]		
Mco1	Manufacture with lower cost than competitors	-	-
	Flexibility	(.75)	
Mco2	Make rapid design changes		.73
Mco3	Introduce new products quickly		.74
Mco4	Make rapid volume changes		.76
Mco5	Make rapid product mix changes		.79
	Quality	(.76)	
Mco7	Manufacture with low defect rates		.82
Mco8	Provide high performance products		.81
Mco9	Offer reliable products		.86
	Delivery	(.74)	
Mco10	Provide fast delivery of products		.89
Mco11	Deliver products on time as promised		.89
	Service	(.69)	
Mco12	Provide effective after- sales services		.83
Mco13	Provide product support effectively		.83
Mco14	Make products easily available		.65
Mco15	Customise products to customer needs		.58

(1) Because cost has only one item, its reliability and factor loadings cannot be computed.

All of the competitive capabilities are accounted for in the five factors except item Mco6 which stands for 'offering broad line of products'. Its low reliability indicates that this capability might not be one of the main responsibilities of the manufacturing function.

The measurement model for manufacturing competence is, therefore. depicted in Figure 11.7 which shows that manufacturing competence construct is defined by the new variables Mcd1 - Mcd5.

Figure 11.7
Measurement model for manufacturing competence



Mcd1. Cost
Mcd2. Flexibility
Mcd3. Quality
Mcd4. Delivery
Mcd5. Service

Table 11.14 presents the results of the reliability tests. After inspecting the reliability of each indicator, it is observed that the item Mcd1 shows both poor reliability and low item-to-total correlation compared with the rest of the items.

The values of composite reliability and coefficient alpha for this model are satisfactory, however, the shared variance value of .3800 suggests that only about 38% of the variance is accounted for by the construct.

The rest of the variance is due to measurement error. Thus in order to improve the shared variance, item Mcd1 is eliminated.

Table 11.14
Reliability estimates for the measures of manufacturing competence

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Mcd1	.0625	.2222	.7702
Mcd2	.4096	.5650	.6040
Mcd3	.4761	.5176	.6217
Mcd4	.4761	.5518	.6008
Mcd5	.4761	.5065	.6252
Composite reliability	.7387		
Shared variance	.3800		
Coefficient alpha	.6952		

Table 11.15
Reliability estimates for the measures of manufacturing competence- Revised set

Item	Indicator reliability	Item-to-total correlations	Alpha if item is deleted
Mcd2	.4624	.5401	.7313
Mcd3	.4489	.5830	.7095
Mcd4	.4489	.5808	.7122
Mcd5	.5476	.5864	.7075
Composite reliability	.7727		
Shared variance	.4599		
Coefficient alpha	.7702		

The results of the revised model are shown in Table 11.15. The values of coefficient alpha, item-to-total correlations and the shared variance have all improved. The item eliminated, Mcd1 which stands for 'manufacturing with lower costs than competitors', indicates that cost, for the sampled firms, is not a critical performance measure since they tend to compete on other factors as the exploratory analysis in the previous chapter suggested. This result will be discussed in more detail in chapter thirteen.

Thus, taken together, the internal consistency reliability tests provide good support for the four-indicator model of manufacturing competence which are composed of flexibility, quality, delivery, and service.

11.3: Unidimensionality and Convergent Validity

Unidimensionality denotes that there exists only one latent variable for a set of observed variables (Hattie, 1985). Convergent validity means that the measures of a construct correlates highly with similar measures that are designed to measure the same or theoretically related construct. They are tested together, using LISREL, through the evaluation of maximum-likelihood parameters estimates with the accompanying chi-square statistic (χ^2) and its p-value.

The chi-square statistic (χ^2) provides support of how well the data fit the model. The smaller the value of χ^2 the better the fit. With respect to the p-value, it is a measure of the probability of getting a larger χ^2 when the specified model is a true reflection of reality. Thus, a large p-value is desirable. Lawley and Maxwell (1971) recommended a p-value that is greater than 0.10 for an indication of good fit. However, Bagozzi and Yi (1988) suggested that p-values as low as 0.01 can sometimes be accepted especially for newly developed constructs.

Cohen (1977) recommended that considerations of parameter estimate magnitude, also called 'effect size', must accompany the preceding tests. The standardised parameter estimates in LISREL approximate these 'effect sizes' which are analogous to factor loadings in exploratory factor analysis. The values of standardised parameter estimates that can be considered acceptable for effect size is 0.30 or over. The significance of considering 'effect sizes' is that they give evidence that

> 'each indicator loading is of substantive significance, and...the measurement model cannot be improved by eliminating any particular indicator. In other words, there appears to be convergence in measurement among the indicators' (Grey, 1994, p. 162).

In addition to Cohen's recommendation, the t-statistic is used. If the t-value exceeds the critical value of 1.96 which is associated with the 0.05 significance level, then that is supportive of the model structure, which means that the manifest variables are related significantly to the latent variable (Anderson and Gerbing, 1988).

Following the previous assessments for reliability, the assessments for unidimensionality and convergent validity are also conducted for each latent variable separately.

11.3.1: Strategic Manufacturing Effectiveness

Strategic manufacturing effectiveness is measured by five summated indicators. One indicator, Std3, was eliminated because of poor reliability. Table 11.16 presents the results for unidimensionality and convergent validity.

Table 11.16
Unidimensionality and convergent validity estimates for the measures of strategic manufacturing effectiveness

Item	ML Estimates	Standardised Estimates	t-value
Std1	1.00	.59	-
Std2	.85	.60	7.05
Std4	.90	.65	7.86
Std5	1.07	.70	8.21
Std6	.83	.49	6.53
Std7	1.02	.49	
Model Fit			
	χ^2	22.3	
	df	9	
	p	.008	

The t-values, which are all significant, suggest that the six indicators are associated with the latent variable, and the standardised estimates are all above the .30 minimum limit. However, the chi-square (χ^2) and accompanying degrees of freedom (df) values indicate that data do not fit the model well.

One way of improving model fit is through the utilisation of modification indices that are provided by LISREL by allowing for correlation between error terms. Leading researchers in structural equation modelling like Fornell (1983), and Bagozzi (1983) pointed that such correlations between residuals (1) must be justified theoretically and (2) should not change significantly the values of parameter estimates.

Taking into account these two conditions, and consulting the modification indices, the error terms of items Std5 and Std4, and Std5 andStd6 are allowed to correlate. These correlations resulted in the following satisfactory statistics: (χ^2 = 9.86, df =7, p=.20). The rationale for allowing the error terms to correlate is as follows:

Item Std4 stands for 'resources improvements' and item Std5 stands for 'quality programmes'. Resources improvements which include the training of managers and workers can influence some quality programmes such as implementing quality circles and zero defects. Also item Std6 which stands for 'information systems' is related to the implementation of statistical quality control. Thus, these items might not be totally independent of one another. The consequences of that is the correlation of their error terms.

Thus, the various statistics altogether provide strong support for the unidimensionality and convergent validity of the six-indicator measurement model.

11.3.2: The Attitude of Top Managers Towards Manufacturing

This latent variable is measured by three indicators. Three other indicators, Att3, Att4, and Att5, were eliminated because they did not satisfy reliability criteria. Because the three-indicator model is just-identified[1], it was tested using tau-equivalent instead of congeneric measures, Tau-equivalent measures mean that the factor loadings are equal to one another ($\lambda_1 = \lambda_2 = \lambda_6$). Gray (1994) noted that tau-equivalent procedure 'involves a more rigorous model-testing condition

[1] A just-identified model is a model where the number of unknown parameters to be estimated and the number of equations are exactly equal. So there is zero degree of freedom. On the other hand, an over-identified model, which is preferable, has more equations than unknowns and thus positive degrees of freedom. For a comprehensive treatment of identification, and the difference between tau-equivalent and congeneric models, readers are referred to Bollen (1989).

stipulating that all items are equally good indicators of the latent variable' (p. 170).

Table 11.17
Unidimensionality and convergent validity estimates for the measures of the attitude of top managers towards manufacturing

Item	ML Estimates	Standardised Estimates	t-value
Att1	.84	.70	17.24
Att2	.84	.71	17.24
Att6	.84	.64	17.24
Model Fit			
	χ^2	4.29	
	df	2	
	p	.12	

Table 11.17 presents the results for unidimensionality and convergent validity. The chi-square (χ^2) statistic and the p-value suggest that data fit the model well. The t-values are all significant, and the standardised parameter estimates are well above the 0.30 level. Thus, there is strong support for the unidimensionality and convergent validity of the three-indicator measurement model.

11.3.3: The Involvement of manufacturing managers

This latent variable is measured by four indicators. One indicator, Inv5, was eliminated because it did not satisfy reliability criteria. The results for unidimensionality and convergent validity are presented in Table 11.18.

The chi-square (χ^2) statistic and p-value indicate that data do not fit the model, however, the standardised parameter estimates are above 0.30, and all t-values are significant at the 0.05 level.

Table 11.18
Unidimensionality and convergent validity estimates for the measures of the involvement of manufacturing managers in setting the strategic direction of the firm

Item	ML Estimates	Standardised Estimates	t-value
Inv1	1.00	.54	-
Inv2	1.26	.60	6.88
Inv3	1.90	.73	7.44
Inv4	1.76	.70	7.38
Model Fit			
	χ^2	24.08	
	df	2	
	p	.000	

In order to improve model fit, error terms of items Inv1 and Inv2 are allowed to correlate, as was done previously for some of the indicators of strategic manufacturing effectiveness.

Item Inv1 stands for 'manufacturing managers seek to understand their company's business strategy and the kind of competitive advantage it is pursuing', and item Inv2 stands for 'manufacturing managers view their roles as being reactive'. If a manufacturing manager seeks to understand his firm's business strategy, then such an involvement should make him more proactive to the demands of his company. Thus, these two items may not be independent of each other. In such circumstances, it is allowable to let the error terms of the two items correlate. By letting them correlate, the chi-square (χ^2) statistic and p-value are as follows: (χ^2= 2.98, df = 1, p= .084). These values suggest that data fit the model well. Thus, the new results provide strong support for the unidimensionality and convergent validity of the four-indicator measurement model.

11.3.4: Formulating Manufacturing Strategy

This latent variable is measured by four indicators. Two indicators, For2 and For6, were eliminated because they did not satisfy reliability criteria.

Table 11.19
Unidimensionality and convergent validity estimates for the measures of formulating manufacturing strategy

Item	ML Estimates	Standardised Estimates	t-value
For1	1.00	.62	-
For3	1.18	.74	7.48
For4	.88	.55	6.84
For5	.93	.53	6.65
Model Fit			
	χ^2	5.23	
	df	2	
	p	.073	

Table 11.19 presents the results of the tests. The chi-square (χ^2) and accompanying degrees of freedom (df) values indicate that data fit the model. T-values, which are all significant, suggest that the four indicators are associated with the latent variable. All of the standardised parameter estimates are well above the 0.30 level. Thus, these tests altogether provide support for the unidimensionality and convergent validity of the four-indicator measurement model.

11.3.5: Manufacturing Proactiveness

This latent variable is measured by three indicators. No indicator was eliminated during the reliability tests. The model is just-identified because it has only three indicators. Hence, it was tested using tau-equivalent measures.

Table 11.20
Unidimensionality and convergent validity estimates for the measures of proactiveness

Item	ML Estimates	Standardised Estimates	t-value
Pro1	.52	.58	13.38
Pro2	.52	.61	13.38
Pro3	.52	.46	13.38
Model Fit			
	χ^2	1.45	
	df	2	
	p	.48	

Table 11.20 presents the results for unidimensionality and convergent validity for this latent variable. The chi-square (χ^2) statistic and p-value indicate that data fit the model extremely well. The t-values are significant and the standardised parameter estimates are all above the 0.30 level. Thus, there is strong support for unidimensionality and convergent validity of the three-indicator measurement model.

11.3.6: Co-ordination with Other Functions

This latent variable is measured by three indicators. One indicator, Coo4, was eliminated during the reliability tests. This model too is

d therefore it was tested using tau-equivalent

Table 11.21 shows the results for unidimensionality and convergent validity for this latent variable. The t-values are significant and the standardised estimates are high but the value of the chi-square (χ^2) statistic indicates that data do not fit the model well. By checking the modification indices, the error terms of Coo1 and Coo3 are allowed to correlate. Item Coo1 stands for 'interactive development of business, manufacturing, and other functional strategies' and item Coo3 stands for 'transfer of "know-how" between functions'. The consequence of functions sitting together to develop strategies is the exchange of information and knowledge between them. After allowing for error terms to correlate, the values of chi-square statistics are (χ^2 = .02, df =1, p=.89), which indicate that data fit the model well.

Table 11.21
Unidimensionality and convergent validity estimates for the measures of co-ordination between manufacturing and other functions

Item	ML Estimates	Standardised Estimates	t-value
Coo1	.80	.73	19.66
Coo2	.80	.77	19.66
Coo3	.80	.81	19.66
Model Fit			
	χ^2	10.51	
	df	2	
	p	.005	

Thus, there is strong support for unidimensionality and convergent validity of the three-indicator measurement model.

11.3.7: Manufacturing Competence

Manufacturing competence is measured by four summated indicators. One indicator, Mcd1, was eliminated because of poor reliability. Table 11.23 presents the results for unidimensionality and convergent validity.

Table 11.23
Unidimensionality and convergent validity estimates for the measures of manufacturing competence

Item	ML Estimates	Standardised Estimates	t-value
Mcd2	1.00	.63	-
Mcd3	1.12	.70	8.57
Mcd4	1.25	.68	8.48
Mcd5	1.14	.70	8.57
Model Fit			
	χ^2	7.44	
	df	2	
	p	.024	

The t-values are all significant which suggest that the four indicators are associated with the latent variable. The standardised parameter estimates also are well above the 0.30 level. However, the chi-square (χ^2) statistics indicate that data do not fit the model well. Modification indices indicate that items Mcd2 and Mcd3 should be allowed to correlate. These two items stand for flexibility and quality respectively. For a firm to be able to make rapid design changes, introduce new products quickly, make rapid volume changes, and make rapid product mix changes, it should be able to manufacture with low defect rates and offer reliable products. Thus, the two summated items that measure flexibility and quality are connected.

By allowing the two items to correlate, the values of chi-square statistics are (χ^2 = .018, df =1, p=.89) which indicate the revised model fits the data well. Thus, the tests provide support for the unidimensionality and convergent validity of the four-indicator measurement model of manufacturing competence.

The seven latent variables were further subjected separately to exploratory factor analysis. Each time, only a single eigenvalue greater than one came out, indicating that the latent variables are unidimensional.

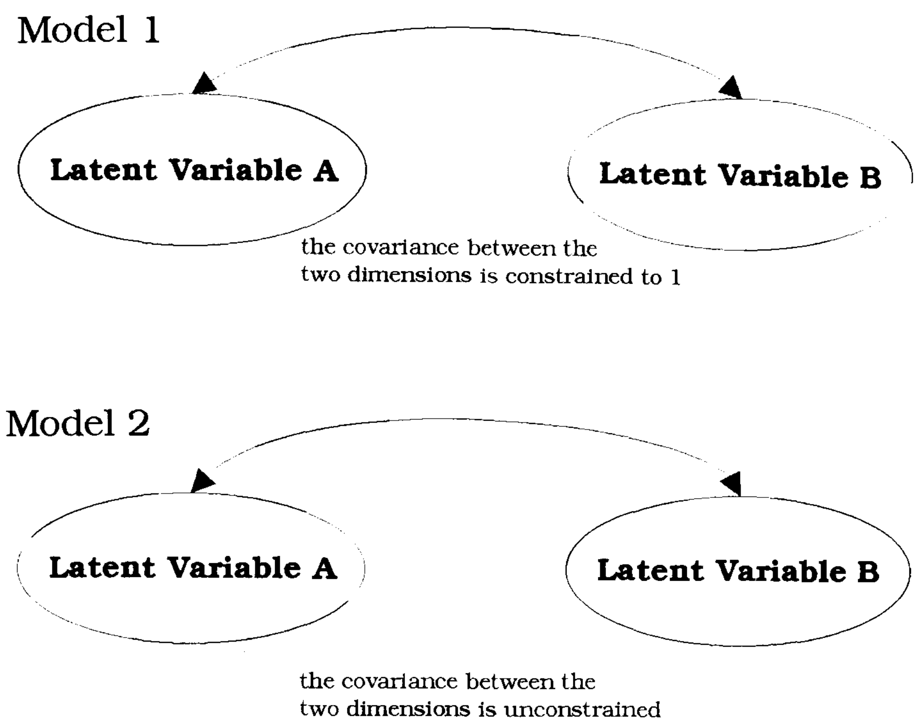
11.4: Discriminant Validity

Discriminant validity is assessed by testing if correlation between each pair of latent variables is substantially different from unity (Venkatraman, 1989). For each pair, two models are compared; one with the correlation constrained to the value one, and the other one unconstrained, as depicted in Figure 11.8. Discriminant validity is attained if the fit of the unconstrained model had substantially better fit than the constrained model (Anderson and Gerbing, 1988).

In order to fit the latent variables in Table 11.24, the abbreviations of these latent variables are used. They are:

Std: Strategic manufacturing effectiveness
Att: Attitude of top managers towards manufacturing
Inv: Involvement of manufacturing managers in setting the strategic direction of the firm
For: Formulating manufacturing strategy
Pro: Proactiveness
Coo: Co-ordination between manufacturing and other functions
Mcd: Manufacturing competence

Figure 11.8
Assessment of Discriminant Validity: Unconstrained and Constrained Models Representing the Relationship Between Two Latent Variables
Adapted from Gray, 1994, p. 181



Anderson and Gerbing (1988) suggested that if a group of chi-square difference tests are conducted, then 'the significance level of each test has to be adjusted so that "true" overall significance level for the tests is maintained'. Since there are 21 tests in the discriminant validity assessment, and the overall significance level is 0.05, the adjusted significance level is calculated as 0.0025[1]. The chi-square value for this significance level is 9.1. Thus, any difference in chi-square value of more than 9.1 between the constrained and unconstrained models means that discriminant validity is achieved.

[1] The equation that Anderson and Gerbing (1988, p. 416) provided for calculating the adjusted significance level is $a_0 = 1 - (1 - a_i)^t$ where a_0 is the overall significance level, usually .05, a_i is the adjusted significance level, and t is the number of tests to be conducted.

Table 11.24 shows the chi-square and degrees of freedom values for the constrained and unconstrained models and their difference. All the difference chi-square values indicate that there are significant differences between constrained and unconstrained models for all pairs of latent variables. Thus it is concluded that the tests conducted provide evidence for discriminant validity for all latent variables.

Table 11.24
Assessment of discriminant validity

Description	χ^2_c	df_c	χ^2_u	df_u	χ^2_d
Std with					
Att	172.09	27	40.16	26	131.93
Inv	267.84	35	79.92	34	187.92
For	86.84	35	65.78	34	21.06
Pro	80.95	27	61.42	26	19.53
Coo	145.39	27	54.56	26	90.83
Mcd	173.05	35	92.57	34	80.48
Att with					
Inv	181.97	14	58.63	13	123.34
For	86.02	14	18.46	13	67.56
Pro	51.29	9	8.00	8	43.29
Coo	104.10	9	13.38	8	90.72
Mcd	171.42	14	19.67	13	151.75
Inv with					
For	177.65	20	66.90	19	110.75
Pro	80.38	14	36.80	13	43.58
Coo	178.32	14	43.44	13	134.88
Mcd	307.99	20	46.73	17	261.26
For with					
Pro	38.79	14	25.90	13	12.89
Coo	68.37	14	44.20	13	24.17
Mcd	125.11	20	32.14	19	92.97
Pro with					
Coo	40.15	9	28.59	8	11.56
Mcd	61.15	14	32.83	13	28.32
Coo with					
Mcd	182.46	14	32.43	13	150.03

11.5: Assessment of the Full Model

The second step in measure purification as stipulated by Anderson and Gerbing (1988) is to assess the full model. This full model comprises both the measurement models of all latent variables and the structural models showing the relationships among the latent variables.

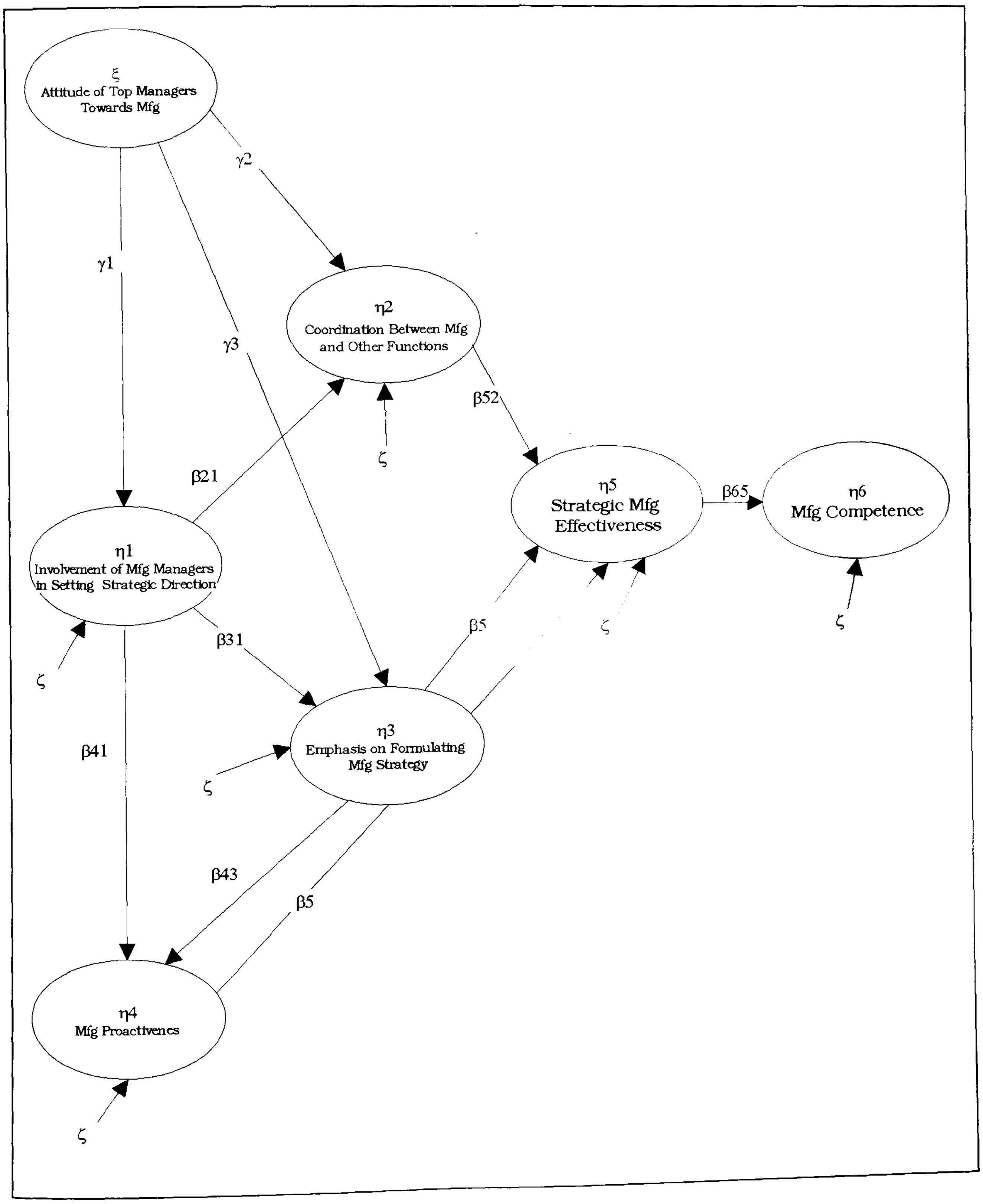
With respect to the measurement models, a distinction is made between the latent variables that are independent from outside effects which are called exogenous latent variables, and the latent variables that are dependent on other latent variables which are called endogenous latent variables.

There is one exogenous latent variable in the model of this study. It is 'the attitude of top managers towards manufacturing'. The rest are endogenous latent variables. The full model which shows the measurement models and structural model is depicted in Figure 11.9. The mathematical equations for measuring the measurement models and the structural models are shown in Appendix C.

The SIMPLIS command language was used to input the full model into the LISREL programme. This command language is simple to use and does not require the mastery of the Greek alphabet and matrix notations.

There were no identification problems associated with the LISREL output which are usually recognised through the presence of theoretically nonsensical estimates. Some of these inconsistent estimates are negative error variances, correlations greater than one, and extremely large parameter estimates (Hair *et al.* 1995). Because none of these problems existed in the output, the fit of the full model is evaluated next.

Figure 11.9
The Structural Model
The γ's indicate the relationships between independent (ξ) and dependent (η) latent variables. The β's indicate the relationships between dependent latent variables. The ζ's are residuals in the measurement of dependent latent variables.



Evaluations of model fit are conducted with the application of goodness-of-fit measures. Goodness-of-fit is a measure of how the actual input matrix corresponds with that expected from the proposed model (Hair *et al.* 1995). There are three types of goodness-of-fit measures. They are absolute fit measures, incremental fit measures, and parsimonious fit measures. The absolute fit measures examine the overall model fit. The incremental fit measures make a comparison between the proposed model and an alternative one. Finally, parsimonious fit measures 'adjust the measures of fit to provide a comparison between models with differing numbers of estimated coefficients' (Hair *et al.* 1995).

The reason why researchers had to develop many goodness-of-fit measures is because traditionally there was only one index and that is the conventional χ^2 statistics and its associated p-value. However, it is known to be sensitive to sample sizes and does not provide information about the degree of fit (Gerbing and Anderson, 1993). Thus, it was necessary to develop other indices that overcome these shortcomings.

11.5.1: Absolute Fit

Absolute fit-measures are usually used to examine the overall model fit through the application of the chi-square statistic (χ^2) and its associated p-value. The χ^2 statistic is the only statistically-based measure of goodness-of- fit in structural equation modelling, all others being essentially descriptive because their distributions are not available (Joreskog and Sorbom, 1989).

To achieve a good fit requires obtaining a small χ^2 value and a large associated p-value. As explained earlier, p-values that are greater than .10 are generally regarded as indicative of satisfactory model fit (Lawley and Maxwell, 1971), even though some researchers have suggested a lower boundary of .01 as being acceptable.

Analysis of the full LISREL model provided the following values: (χ^2 = 584.24, df = 308, $p < .001$). Such values indicate that data do not fit the model adequately. However, as pointed out earlier, exclusive dependence on the χ^2 statistic is not encouraged (Fornell and Lacker, 1981). Thus other overall fit measure are used. One of these is the goodness of fit index (GFI), which ranges in value from 0 (poor fit) to 1 (perfect fit), and its value should ideally exceed 0.90. It is a measure which assesses the degree that covariances expected from the estimated parameters reproduce the sample covariances (Tanaka and Huba, 1984). The value of GFI for the full model is .87 which falls below the recommended level.

Another statistic is root mean square residual (RMSR), which estimates the average of the residuals between observed and estimated input matrices (Hair *et al.*, 1995). It should be close to zero, with values less than 0.1 indicating an acceptable fit (Meyer and Gellatly 1988). The RMSR for the model is .066 which is satisfactory.

The indications, thus far, are mixed. Whereas the chi-square statistic indicates inadequate fit, the RMSR shows better fit for the model, with the GFI value in the borderline between these two measures.

Consequently, before contemplating any changes to the model on the basis of these indices, some incremental and parsimonious fit indices are evaluated first, so that any respecification of the model, if needed, does not rely solely on the absolute fit measures which are primarily sensitive to sample size and degrees of freedom.

11.5.2: Incremental Fit

The indices under this group make comparisons between the fit of the proposed model and the fit of a baseline model that is referred to as the null model.

The normed fit index (NFI), proposed by Bentler and Bonett (1980), is widely used as a measure of incremental fit. Like most other indices it ranges in value from 0 (poor fit) to 1 (perfect fit). Values greater than .90 provide adequate model fit, however values as low as .80 can provide marginal support for the proposed model (Bentler and Bonett, 1980). The value of NFI in this model is .80 which is minimally acceptable.

The other widely used measure is the adjusted-goodness-of-fit index (AGFI), provided by the LISREL model, which is similar to the goodness-of-fit index (GFI), but adjusted by the ratios of the degrees of freedom for the proposed model to the degrees of freedom for the null model (Hair *et al.*, 1995). Its value also ranges from 0 (poor fit) to 1 (perfect fit). AGFI values greater than .90 are considered adequate.

even though values above .80 are taken as indicative of marginal model fit (Hair *et al.* 1995). The AGFI value of .84 for the full model fails to satisfy the .90 criterion, however it meets the .80 level. It is, therefore, indicative of a marginal model fit.

11.5.3: Parsimonious Fit

Parsimonious fit measures are intended to assess goodness of fit relative to the number of estimated coefficients that are needed to achieve that level of fit (Hair *et al.* 1995).

One of the first parsimonious fit measures proposed by Joreskog (1969) is the normed chi-square. This measure is equal to the value of χ^2 for the proposed model adjusted by the degrees of freedom.

Normed $\chi^2 = \chi^2_{proposed} / df_{proposed}$

There is no consensus on the values that represent a good normed χ^2 fit. Hair *et al.* (1995) noted that values less than 1.0 indicate that a model is 'overfitted' by capitalising on chance. With respect to adequate models their values should not exceed 2.0 or 3.0 (Carmines and McIver 1981), with some researchers suggesting a higher limit of 5.0 (Wheaton *et al.* 1977). This measure, however, is subject to the same sample size effects that were pointed out earlier for the likelihood-ratio chi-square statistic.

The LISREL model provides a normed χ^2 value of 1.90, which falls within the most rigorous limits for good model fit. It is taken therefore as providing good evidence for adequate fit of the model.

11.5.4: Model Respecification

Considering that most of the measurement scales in this research are new, the overall evidence from the various indices suggests that the hypothesised full model fits the data marginally well. However, the model is considered for respecification in order to improve further its fit to the data.

The modifications are usually based on the standardised residuals, which are considered significant if their values are ± 2.58 or over (Hair *et al.*, 1995). Also, the modification indices provided by LISREL are utilised for deciding on further changes. Values of modification indices greater than 3.84 are considered significant.

All contemplated changes must be within the permissible boundary of the existent theory. If, for example, deleting an item would substantially modify the model, that item must be retained. That is, because the application of structural equation modelling, as implemented in LISREL, can only contribute to our understanding of social phenomena if they are theory driven, not data driven.

Examinations of both the standardised residuals and the modification indices suggest that a path is added from the latent variable 'strategic manufacturing effectiveness' to the latent variable 'co-ordination between manufacturing and other functions'. This path indicates that there is bi-directional effects between the two latent variables. The outcome from this addition resulted in the chi-square value being reduced by 87.73 ($\chi^2 = 496.51$, df = 307, $p < .001$). Other fit indices changed slightly except for the normed chi-square which improved from 1.90 to 1.62.

There were also error terms for some observed variables that can be allowed to correlate. Some of these changes can be justified theoretically. However, after many preliminary trials to introduce those theoretically-justified changes, the improvement in model fit as measured by the fit indices were modest. Furthermore, these modifications made noticeable changes in the values of structural parameters, something they should not do. Therefore, no more changes were introduced to the model.

11.6: Summary

The process of purifying the seven latent variables in the strategic manufacturing effectiveness framework was conducted in this chapter. This process involved the assessment of reliability, unidimensionality, discriminant validity, and convergent validity. The assessments were conducted using structural equation modelling technique as implemented in LISREL and also the statistical programme, SPSS.

In testing the reliability and validity of the measures, comprehensive details of analyses are presented. That makes it easier for other researchers to scrutinise the method used or apply it in similar research settings.

The two step approach of Anderson and Gerbing (1988) for developing and purifying measures was utilised. This approach calls for purifying the measures of each latent variable individually in step one , and then examining the full model in step two.

The internal consistency reliability assessments provide information about the presence (or absence) of random errors in the measures. The LISREL programme furnished data that were used to calculate three reliability tests. They are indicator reliability, composite reliability and shared variance. Along with these three measures of assessing reliability, three more tests are utilised which are generated from SPSS. They are Cronbach's coefficient alpha, the item-to-total correlations, and the value of alpha if an item is deleted.

Some of the latent variables are measured by a large number of items, and consequently they were reduced using factor analysis. Too many items make the interpretation of the results unwieldy.

Thereafter, unidimensionality and convergent validity of the measures were examined, using LISREL, through the evaluation of maximum-likelihood parameters estimates with the accompanying chi-square statistic (χ^2) and its p-value, the t-values, and the standardised parameter estimates. These tests reveal that there are some items which have correlated errors.

Next, discriminant validity is assessed by testing if correlation between each pair of latent variables is substantially different from unity. For each pair, two models are compare; one with the correlation constrained to one and the other one unconstrained. Discriminant validity is attained if the fit of the unconstrained model had a substantially better fit than the constrained model. The tests conducted provide evidence for discriminant validity for all latent variables.

Finally, the assessment is conducted for the full model which comprises both the measurement models of all latent variables and the structural models showing the relationships among the latent variables.

Evaluations of full model fit are conducted with the application of three types goodness-of-fit measures. They are absolute fit measures, incremental fit measures, and parsimonious fit measures. Absolute fit-measures are examined through the chi-square statistic (χ^2) and its associated p-value, the goodness of fit index (GFI), and the root mean square residual (RMSR). The normed fit index (NFI), and the adjusted-goodness-of-fit index (AGFI), are used as measures of incremental fit. As for measuring parsimonious fit, the normed chi-square is used.

The evidence from the examination of model fit indices suggests that the hypothesised full model fits the data quite adequately, considering that most of the measurement scales in this research are new.

The various tests for reliability and validity of individual latent variables and the assessment of the full model provided this research with a model that is representative of strategic manufacturing effectiveness and its causes and outcomes. The next chapter utilises this model to test the hypotheses underpinning this research.

Chapter 12:

Testing the Hypotheses

12.1: Overview

Chapter three was devoted to the development of the conceptual framework and derivation of research hypotheses underlying this research. In that chapter, it was noted that there are eight hypotheses that are to be tested. The first six of these hypotheses consider the relationships among the seven latent variables in the framework. These hypotheses can therefore be tested using the values and significance of the parameters of the structural equation modelling which are shown in Figure 11.9 in the previous chapter. The seventh hypothesis is tested using cluster analysis, and the last one concerning the effects of types of industry, size of firms, and types of production process on strategic manufacturing effectiveness was tested using contingency tables.

12.2: Testing the Hypotheses

The first six hypotheses are to be tested using results which were obtained from the model development phase of the previous chapter. However, before commencing hypotheses testing, it is important to note there are differences between these two phases of research as Venkatraman (1989) pointed out:

> '(model development) seeks to examine the degree of correspondence between the results obtained using a particular measurement scheme and the meaning attributed to those results. In contrast, [hypothesis testing] focuses on the specific relationships between constructs with a broadly defined theoretical framework, and these relationships are

dependent on the results of the construct validation tests' (p. 956).

Thus the two stages of model development and hypothesis testing are interlinked with model development being a prerequisite for hypothesis testing.

The results of hypotheses testing and their implications are not discussed here, but in the next chapter which is devoted for that purpose.

12.2.1: Hypothesis 1

The attitude of top managers towards manufacturing positively affects the involvement of manufacturing managers in setting the strategic direction of the firm.

The LISREL structural estimate for the relationship between the attitude of top managers and the involvement of manufacturing managers is (γ_{11} = 0.54, t = 5.37, $p < 0.001$). This relationship is significant and thus evidence is provided that the attitude of top managers does influence the involvement of manufacturing managers.

12.2.2: Hypothesis 2

Co-ordination between manufacturing and other functions is positively affected by both the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firm.

The LISREL structural estimate for the relationship between the attitude of top managers towards manufacturing and the co-ordination between manufacturing and other functions is ($\gamma_{21} = 0.19$, $t = 2.26$, $p = 0.012$). This estimate indicates that the relationship is significant.

The LISREL structural estimate for the relationship between the involvement of manufacturing managers in setting the strategic direction of the firm and co-ordination between manufacturing and other functions is ($\beta_{21} = 0.21$, $t = 3.16$, $p < 0.001$) which indicates that it is also significant. So, support is provided for the hypothesis that co-ordination between manufacturing and other functions is positively affected by both the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firm.

12.2.3: Hypothesis 3

> **The emphasis on formulating manufacturing strategy is positively affected by both the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firm.**

The LISREL structural estimate for the relationship between the attitude of top managers towards manufacturing and the emphasis on formulating manufacturing strategy is ($\gamma_{31} = 0.41$, $t = 5.17$, $p < 0.001$) which suggests that this relationship is significant.

The LISREL structural estimate for the relationship between the involvement of manufacturing managers in setting the strategic direction of the firm and the emphasis on formulating manufacturing strategy is (β_{31} = 0.22, t = 3.65, $p < 0.001$). This indicates that this relationship is also significant. That means support is obtained for both parts of this hypothesis.

12.2.4: Hypothesis 4

> **Manufacturing proactiveness is positively affected by the involvement of manufacturing managers in setting the strategic direction of the firm and the emphasis on formulating manufacturing strategy.**

The LISREL structural estimate for the relationship between the involvement of manufacturing managers in setting the strategic direction of the firm and manufacturing proactiveness is (β_{41} = 0.12, t = 1.74, p = 0.041). This indicates that this relationship is significant.

The LISREL structural estimate for the relationship between the emphasis on formulating manufacturing strategy and manufacturing proactiveness is (β_{43} = 0.70, t = 6.24, $p < 0.001$), which suggests that the relationship is also significant.

Thus, there is support for the hypothesis that manufacturing proactiveness is positively affected by both the emphasis on formulating manufacturing strategy and the involvement of manufacturing managers in setting the strategic direction of the firm.

12.2.5: Hypothesis 5

Strategic manufacturing effectiveness is positively affected by (1) the co-ordination between manufacturing and other functions, (2) the emphasis on formulating manufacturing strategy, and (3) manufacturing proactiveness.

The LISREL structural estimate for the relationship between the co-ordination between manufacturing and other functions and strategic manufacturing effectiveness is (β_{52} = 0.52, t = -3.18, $p < 0.001$) which indicates that the relationship is significant but in the opposite direction. Thus this relationship is not supported.

The LISREL structural estimate for the relationship between the emphasis on formulating manufacturing strategy and strategic manufacturing effectiveness is (β_{53} = 0.71, t = 3.51, $p < 0.001$) which indicates that this relationship is significant.

The LISREL structural estimate for the relationship between manufacturing proactiveness and strategic manufacturing effectiveness is (β_{54} = 0.50, t = 2.54, p = 0.006) which indicates that this relationship is also significant.

Thus support is provided for the relationships between strategic manufacturing effectiveness and both the emphasis on formulating manufacturing strategy and manufacturing proactiveness. The other part of this hypothesis which is the relationship between the co-ordination between manufacturing and other functions and strategic manufacturing effectiveness is not supported.

12.2.6: Hypothesis 6

Manufacturing competence is positively affected by strategic manufacturing effectiveness.

The LISREL structural estimate (β_{65} = 0.86, t = 7.80, $p < 0.001$) suggests that the relationship is significant. Thus, there is support for the hypothesis that strategic manufacturing effectiveness positively affects manufacturing competence.

12.2.7: Hypothesis 7

There are four identifiable stages in strategic manufacturing effectiveness as specified by Wheelwright and Hayes (1985).

To test the hypothesis that there are four identifiable stages in strategic manufacturing effectiveness as specified by Wheelwright and Hayes, cluster analysis is used to identify the clusters that the responding firms group into.

It is worth pointing out with respect to this hypothesis that it is concerned only with the identifiability of four stages in strategic manufacturing effectiveness and not with the optimum number of stages that might exist. Thus, the objective here is not to test a hypothesis that there are <u>only</u> four stages in strategic manufacturing effectiveness, but to see if the four stages are apparent in the sample of firms under study. That is because any set of data can be clustered into any number of groups, and deciding on the number of clusters is a thorny issue which cannot be solved easily. Moreover, the statistical tool used to test this hypothesis, which is cluster analysis, is not based on statistical probability theory (Hair *et al.*, 1995). Thus, a researcher cannot test the probability of the existence of a set of clusters as opposed to another set of clusters.

Cluster analysis encompasses a variety of multivariate techniques which are all devoted to the classification of objects that are similar into groups. These techniques can be divided into hierarchical and non-hierarchical varieties. 'Hierarchical' means that once an object is allocated to a cluster it can not be re-assigned to another cluster. The two main types of cluster analysis techniques have their advantages and disadvantages. So, researchers such as Punj and Stewart (1983), Berry *et al.* (1991), and Hair *et al.* (1995) have recommended a two-step cluster analysis method which combines the strengths of the two types. In the first step, hierarchical cluster analysis is applied to produce initial cluster centres estimates and suggest the appropriate number of clusters. Then, in step two, the initial cluster centres estimates are used to get the final cluster centres estimates and allocate the objects into clusters.

Table 12.1 shows results of the application of hierarchical cluster analysis on the variables that measure strategic manufacturing effectiveness which are Std1-Std2, Std4 -Std7. The information in this table helps in identifying the number of clusters that are appropriate. The last column in the table shows the percentage of change in the agglomeration coefficient from one level to the next. If this change is relatively large, then that corresponds to the likely number of clusters. The biggest change is going from a two-cluster solution to a one cluster solution, which therefore indicates that a two-cluster solution is probably more appropriate. However, both four- and three-cluster solutions are plausible. Because of the nature of cluster analysis which does not indicate exactly the number of expected clusters, it is preferable to use it in a more theory-driven fashion (Dowling and Midgley, 1988). Thus, two, three and four cluster solutions were tested to see which one of these is most compatible with the current thinking in manufacturing strategy.

Table 12.1
Analysis of Agglomeration Coefficient for Hierarchical Cluster Analysis

Number of Clusters	Agglomeration Coefficient	Percentage of Change in Coefficient to the Next Level
10	566.2	4.5
9	591.9	4.6
8	619.7	5.3
7	653.0	5.2
6	687.2	6.7
5	732.9	9.9
4	805.7	12.2
3	904.3	15.3
2	1042.8	29.2
1	1347.8	-

Initial cluster centres are computed for the two- to four-cluster solutions, which are then applied to the non-hierarchical cluster analysis technique, called K-means, in the second step. The results for the two-cluster solution are shown in Table 12.2, and that for the three- and four-cluster solutions are placed in Appendix D.

It can be observed that all three solutions are credible. The final cluster centres, for all solutions, are very similar to the initial ones which indicate the stability of the results across the two types of cluster analysis. The last part of Table 12.2 and Appendix D presents the results of significance testing of differences between cluster centres. The probability values for all variables, being 0.000, clearly indicates that there are differences between the clusters for each variable. Thus, it can be concluded that the clusters are distinct from one another.

Table 12.2
Results of K-Means Cluster Analysis

a. Initial Cluster Centres

Cluster	Std1	Std2	Std4	Std5	Std6	Std7
1	3.9863	3.5467	4.0568	3.5330	4.1291	4.3791
2	3.0752	2.7235	3.2891	2.7115	3.1947	2.9204

b. Final Cluster Centres

Cluster	Std1	Std2	Std4	Std5	Std6	Std7
1	3.9834	3.5483	4.0589	3.5359	4.1326	4.3867
2	3.0877	2.7281	3.2924	2.7140	3.1974	2.9211

c. Average Cluster Centres for Each Cluster

Cluster	Average
1	3.94
2	2.99

d. Number of Cases in Each Cluster

Cluster	Cases
1	181
2	114

e. Significance Testing of Differences Between Cluster Centres

Variable	Cluster Mean Square	D.F.	Error Mean Square	D.F	F Value	Probability
Std1	56.1167	1	.624	293	89.8123	.000
Std2	47.0628	1	.417	293	112.7186	.000
Std4	41.0984	1	.409	293	100.4766	.000
Std5	47.2470	1	.492	293	95.9386	.000
Std6	61.1782	1	.587	293	104.1395	.000
Std7	150.2603	1	.693	293	216.6459	.000

However, the average cluster centres for each cluster (part c of Table 12.2 and Appendix D) suggest that the differences between clusters for the three- and four-cluster solutions cannot be interpreted easily since they are too small. Whereas for the two-cluster solution, the average cluster centre for cluster one is close to 4 and the average cluster centre for cluster two is around 3. Taking into account that the scale used to measure the variables of the strategic manufacturing effectiveness has the following points: (1 = no emphasis, 3 = moderate emphasis, 5 = great emphasis), it can be postulated that an average score of 2 indicates that a firm is in stage one according to Wheelwright and Hayes' framework, and an average close to five corresponds to stage four. So, stage two requires a score of three, and stage three requires a score of four. Accordingly, the information above suggests that the first cluster can be associated with stage three and the second cluster can be associated with stage two.

This exercise in the application of cluster analysis suggests that, with the four stages framework of Wheelwright and Hayes (1985) in mind, only the second and third stages were apparent in the firms under study. The implications of this finding and the results from the testing of the seven hypotheses are discussed in the next chapter.

12.2.8: Hypothesis 8

(H8): There are differences in manufacturing performance among the four stages with respect to:

(H8a): the type of industry,

(H8b): the size of the firm,

(H8c): the type of production process used.

This hypothesis was tested using the contingency tables in the SPSS programme as shown in the next three tables in this page. Please note that the expected values are shown in brackets.

Table 12.3
A Contingency Table Showing Types of industry by Their Stages

Types of Industry	Stage three	Stage two	Row Total
Refrigerating machinery and air conditioning SIC Code=3284	10 (11.1)	7 (5.9)	17 27.9%
Basic electrical equipment SIC Code=3420	6 (11.1)	11 (5.9)	17 27.9%
Motor vehicle parts SIC Code=3530	24 (17.7)	3 (9.3)	27 44.3%
Column Total	40 65.6%	21 34.4%	61 100.0%

Chi-square = 13.74921, Significance. = .00103

Table 12.4
A Contingency Table Showing the Size of Firms by Their Stages

Size of firms with respect to number of employees	Stage three	Stage two	Row Total
Less than 250	96 (105.5)	76 (66.5)	172 58.3%
between 250 and 1000	72 (65.7)	35 (41.3)	107 36.3%
more than 1000	13 (9.8)	3 (6.2)	16 5.4%
Column Total	181 61.4%	114 38.6%	295 100.0%

Chi-square = 6.48768, Significance = .03901

Table 12.5
A Contingency Table Showing Types of Production Process by Their Stages

Types of Production Process	Stage three	Stage two	Row Total
job shop	24 (33.7)	31 (21.3)	55 18.6%
batch	89 (90.8)	59 (57.2)	148 50.2%
assembly line	52 (42.3)	17 (26.7)	69 23.4%
continuous flow	16 (14.1)	7 (8.9)	23 7.8%
Column Total	181 61.4%	114 38.6%	295 100.0%

Chi-square = 13.73911, Significance. = .00328

It can be observed that the chi-square values are significant for the three sub-hypotheses. That means the types of industry, the sizes of firms, and the types of production process used have mediating effects on manufacturing effectiveness. This observation, as well as all other findings are discussed in the next chapter.

12.3: Summary

Eight hypotheses were tested in this chapter. These hypotheses were derived from the conceptual framework underpinning this research. The results from testing the first six hypotheses are summarised in Table 12.6.

As for the seventh hypothesis which states that there are four identifiable stages in strategic manufacturing effectiveness as specified by Wheelwright and Hayes, the application of cluster analysis revealed that only two stages are apparent in the sample of study. The last hypothesis revealed that types of industry, the sizes of firms, and the types of production process used have mediating effects on manufacturing effectiveness. The implications are discussed in next chapter.

Table 12.6
Summary of Hypotheses Testing

	Relationships between	**and**	**Result**
H (1)	The attitude of top managers towards manufacturing	the involvement of manufacturing managers in setting the strategic direction of the firm	supported
H (2)	Co-ordination between manufacturing and other functions	the attitude of top managers towards manufacturing	supported

		the involvement of manufacturing managers in setting the strategic direction of the firm	supported
H (3)	The emphasis on formulating manufacturing strategy	the attitude of top managers towards manufacturing	supported
		the involvement of manufacturing managers in setting the strategic direction of the firm,	supported
H (4)	Manufacturing proactiveness	the involvement of manufacturing managers in setting the strategic direction of the firm	supported
		the emphasis on formulating manufacturing strategy	supported
H (5)	Strategic manufacturing effectiveness	co-ordination between manufacturing and other functions	Not supported
		the emphasis on formulating manufacturing strategy	supported
		manufacturing proactiveness	supported
H (6)	Manufacturing competence	strategic manufacturing effectiveness	supported

Chapter 13:

Discussion of Results and Conclusions

13.1: Overview

Despite the growing interest in manufacturing strategy research, both the substantive and measurement streams in the field are mainly underdeveloped. Although the effectiveness of manufacturing has been a topic of interest to researchers, there has been little empirical research effort to validate the framework of strategic manufacturing effectiveness that was proposed by Wheelwright and Hayes (1985). Previous research in this topic has suffered from the lack of theoretical relationships among a set of variables that are supposed to influence and measure strategic manufacturing effectiveness. This research has attempted to redress these shortcomings with a comprehensive causal model that brought related factors together in a form that made their relationships more explicit and easier to test.

This chapter summarises and explains the implications from model development and hypotheses testing in the previous two chapters. The contributions of this study from the theoretical, practical, and methodological perspectives are also detailed. Finally, limitations of the research and suggestions for future research are presented.

13.2: Results from Purification of Measures

The seven factors that measure strategic manufacturing effectiveness and its causes and outcomes were purified in chapter 11 using reliability and validity tests. During the assessments, some items at the lower threshold of reliability and validity were deleted. However, it can be argued that these items should not have been deleted because they represent different aspects of the factors they are supposed to measure, and therefore if deleted, these factors might not be measured comprehensively. The response to this argument is that even though the items were initially chosen carefully for each factor, some had to be eliminated because they have been specified incorrectly and therefore their deletion purifies the measures. This is specially true for the items that measure the five factors that cause strategic manufacturing effectiveness, since they are new and subjective and it is anticipated that such misspecifications might occur.

It is worth pointing out that if an item is specified incorrectly to a factor, then its deletion can be justified on statistical grounds, that is to purify the measures. However, it is difficult to justify it substantively. That is because such misspecifications are usually due to the existence of another distinct but similar factor which the misspecified item is measuring. Problems due to model misspecifications can be corrected in future research which should take into account limitations encountered in earlier studies.

On the other hand, there are a few items that have been deleted despite the fact that they are very plausible. They could not have been misspecified since the arguments for their inclusion in the model are overwhelming. Such deletions must be justified substantively. This is true for the items that measure both strategic manufacturing effectiveness and its outcome (manufacturing competence) which have been developed, in the past, by researchers working for the Manufacturing Futures Survey Project (e.g., Ferdows and De Meyer, 1990).

One such item eliminated is Mcd1 that stands for 'manufacturing with lower costs than competitors', which implies that cost, for the sampled firms, is not a critical performance measure. This deletion can be justified on the grounds that these firms tend to compete on other dimensions such as better quality and service. The exploratory data analysis in chapter ten has already suggested that most of the firms in the sample are small to medium enterprises which manufacture their products to order. In such circumstances, firms tend to compete through other means. Thus, it is expected that cost is not the most important competitive capability.

Support for the deletion of this item can also be obtained from the sandcone model of Ferdows and De Meyer (1990) which states that cost reduction is attained permanently if other competitive capabilities have been achieved. Ferdows and De Meyer (1990) stated that

> 'Lasting cost improvements in manufacturing result from improvements in quality, dependability and fast reaction capabilities, and only rarely as the direct result of specific action programmes' (p. 130).

For example, when Cummins Engine Co. (UK) found itself trailing its Japanese competitors in responsiveness to customers demands (delivery), it implemented just-in-time (JIT) manufacturing. That resulted in the reduction of lead-time from 20 to 3 days. Also, as the indirect consequence of JIT implementation, overhead costs were reduced by 70% (Mullins, 1989).

So, the firms under study are probably emphasising at the moment quality and other competitive capabilities which could eventually result in cost reduction in the future. By looking at Table 13.1, it can be observed that the strength of firms in achieving lower cost is last. This means the focus is on other capabilities.

Table 13.1
Averages of Strengths in Competitive Capabilities

Competitive Capability	Strength
Cost	3.36
Flexibility	3.44
Quality	3.95
Delivery	3.75
Service	3.75

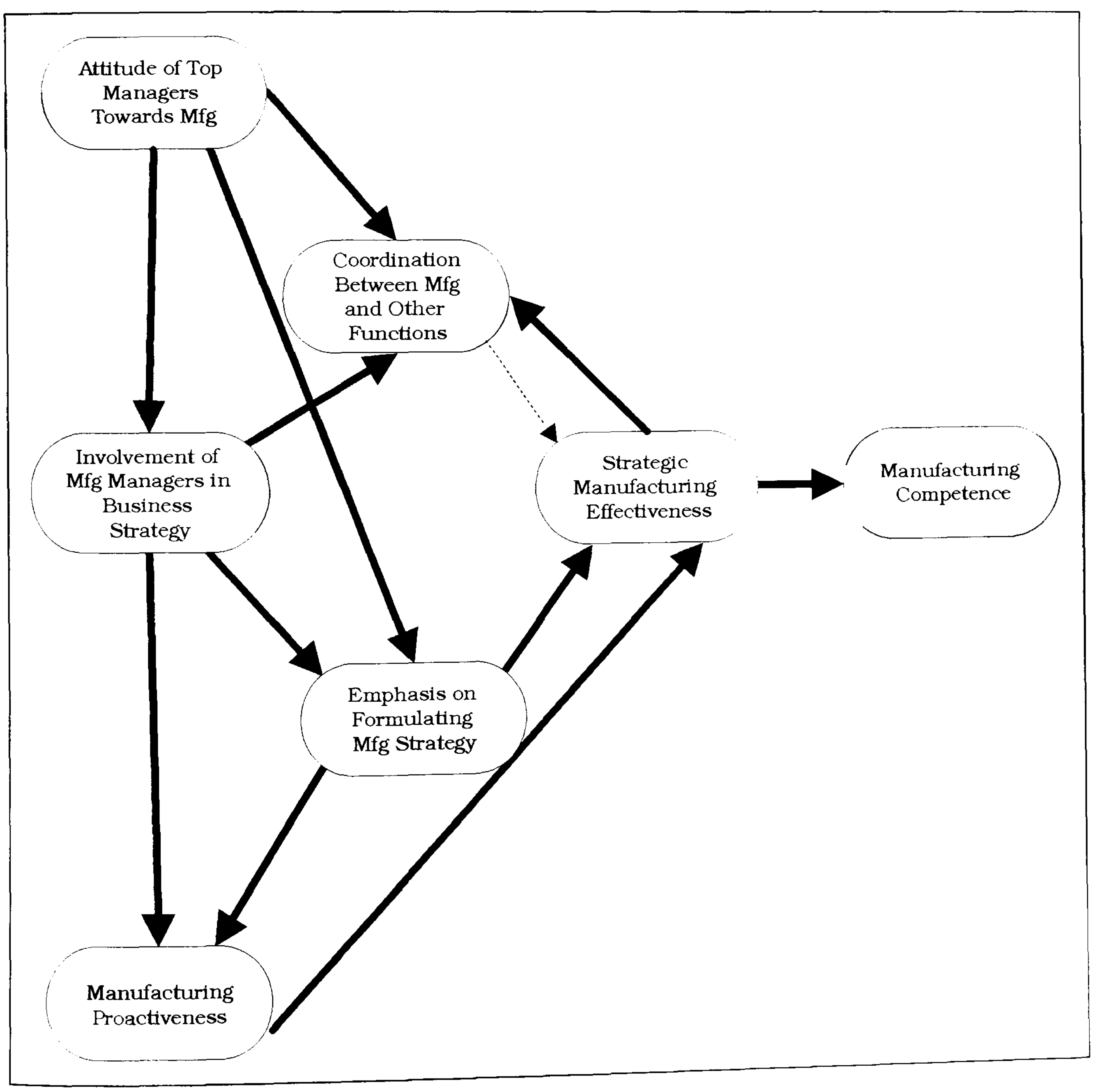
13.3: Results from Hypotheses Testing

Figure 13.1, on the next page, illustrates the relationships that were supported, presented by bold lines in the figure. Only one relationship is not supported and it is shown in a dotted line.

The results from hypotheses testing indicated, as expected, that the attitude of top managers towards manufacturing positively affects the involvement of manufacturing managers in corporate strategy development, and both of these two factors positively affect the co-ordination between manufacturing and other functions.

The result of the first hypothesis confirms the importance of the involvement of top management in manufacturing strategic decisions. Reitsperger and Daniel (1990) found that one of the reasons for the current successes of Japanese manufacturers over their American counterparts is the strategic commitment of their top managers who are 'never far from the *production picture*'. This same observation was noted before by Hayes and Abernathy (1980), and Cusumano (1988). The result of the second hypothesis supports the findings of Rafii and Miller (1994) who noted that communication of the firm's competitive strategy to its manufacturing function is a prerequisite for the integration of manufacturing into the corporate mainstream.

Figure 13.1
The Conceptual Model with Significant Relationships Shown in Bold Lines



Furthermore this result supports the study of Miller and Hayslip (1989) who found that if communication channels are open between manufacturing on one hand, and both top management and other functional managements on the other hand, then the chances of strategic co-ordination between manufacturing and other functions are enhanced. In addition, Hax and Majluf (1984) and Skinner (1985) have postulated the positive relationship between the consistency of strategic directions, within functions and management hierarchy, and performance.

The emphasis on formulating manufacturing strategy was found also to be positively affected by the attitude of top managers towards manufacturing and the involvement of manufacturing managers in strategic debates. This result is in line with other evidence (e.g., Cleveland *et al.*, 1986; Swamidass and Newell, 1987; and Hayes *et al.*, 1988) that senior managers and manufacturing managers have to be involved upfront for any effort of formulating and implementing manufacturing strategy to succeed.

Manufacturing proactiveness was also found to be positively affected by the involvement of manufacturing managers in strategic debates and the emphasis on formulating manufacturing strategy. This result is comparable to the earlier empirical finding of Ward *et al.* (1994) that manufacturing involvement and capability building programmes cause manufacturing proactiveness.

As for the causes of strategic manufacturing effectiveness, both manufacturing proactiveness and the emphasis on formulating manufacturing strategy positively affect it.

On the other hand, co-ordination between manufacturing and other functions does not influence it directly. The explanation for this finding is that maybe this factor is not a cause of strategic manufacturing effectiveness but an outcome. This is supported by the path introduced during the model modification stage in chapter eleven which points from strategic manufacturing effectiveness to this factor.

As opposed to the manufacturing function, Hayes and Wheelwright (1984) noted that for the business as a whole to be effective, it is required that

> 'each functional strategy must support, through a consistent pattern of decisions, the competitive advantage being sought by the business strategy' (p. 29).

Thus it can be inferred from the argument above that co-ordination between manufacturing and other functions is a prerequisite for an effective business, and it is an outcome of an effective manufacturing function.

Results from hypotheses testing also indicated the causal effect of strategic manufacturing effectiveness on manufacturing competence. The higher the effectiveness of manufacturing the more competent it becomes. This result does not contradict the conclusion of De Meyer and Ferdows (1990, p. 130), who studied the influence of improvement programmes on performance, and noted that

> 'There are no simple cause-effect relationships between improvement programmes and manufacturing performance'.

That is because the relationships between competitive priorities and manufacturing improvement programmes are complex. However the cumulative effect of manufacturing improvement programmes is superior overall manufacturing competence.

Therefore, this result implies that in order to improve a particular competitive priority, for example quality, does not mean making a single choice like implementing zero defects, but requires many choices made in cohesion. These choices will then have positive effects, not just on the intended priority which is quality, but also on other competitive priorities.

As a continuation to the preceding argument, individual improvement programmes can have positive effects on many competitive priorities. To illustrate, the manufacturing unit at AT&T in Clark, New Jersey, managed to transform itself from working in a rigid hierarchical environment through the creation of cross-functional teams. These teams made major contributions in increasing the levels of quality, speeding up delivery, and reducing cost (Williams, 1996).

The results from the application of cluster analysis suggested that there are only two stages (from the four) that are apparent in the firms under study. These two stages are stage two (externally neutral) and stage three (internally supportive). This finding, as indicated in the previous chapter, does not imply that the other two stages (one and four) do not exist. What it really implies is that the firms in the sample have surpassed the demands of stage one but have yet to move to stage four which has more demanding requirements compared with stage three.

Finally, the results of testing the last hypothesis indicated that types of industry, the sizes of firms, and the types of production process used have mediating effects on strategic manufacturing effectiveness. With respect to types of industries, and with reference to Table 12.3 in the previous chapter, it can be observed that the majority of the manufacturers of motor vehicle parts are in stage three whereas most of the firms that are manufacturing basic electrical equipment are in stage two. This indicates that forces of competition and the demands of customers can sometimes drive firms in an industry to have more strategically effective manufacturing function. This is true for motor vehicle parts manufacturers who have to adopt such initiatives as JIT since they have been implemented by most of the motor vehicle manufacturers.

However, firms which belong to industries that do not have a clear role for manufacturing can still manage to make it a competitive advantage. That is because in an earlier observation, Slack (1991) noted that the contribution of manufacturing is most evident in mature industries like domestic appliances, consumer electronics and motor cycles. Manufacturing in such industries was considered, at one time, as incapable of providing any significant competitive advantage for firms belonging to these industries. Apart from controlling costs, adhering to schedules, and maintaining acceptable levels of quality, manufacturing has no other role to play. For competitive advantage, firms have to rely on marketing to sell their goods. However, the success stories of many firms, most of which are Japanese, is testimony to how manufacturing can play an active role in providing a cutting edge for a firm willing to invest in it.

The same is applicable to the effect of size of firms. By referring to Table 12.4 in the previous chapter, it can be observed that as firms grow larger, more of these firms are found in stage three, as opposed to stage two. The reason for finding more small firms in lower stages was provided by Marucheck *et al.* (1990) who found in their study of the manufacturing strategy process in practice that in small firms

> 'Corporate objectives frequently served as the manufacturing objectives; and in some cases, the articulated manufacturing objectives were really tactical in nature since they were directed toward achieving a certain strategy as opposed to broad corporate objectives' (p. 115).

As for the type of production process used, the classification of Hayes and Wheelwright (1979) was used to investigate its mediating effect on strategic manufacturing effectiveness. The four discrete production process types are jumbled flow (job shop), disconnected line flow (batch), connected line flow (assembly line), and continuous flow. The results indicated that firms using assembly line and continuous flow processes are more likely to be in stage three. This observation is true to a lesser extent with the batch process users. However, more firms that use job shop process are in stage two. This result about the types of production processes used is related to the earlier result about sizes of firms. Smaller firms are generally the users of job shop process, whereas large firms tend to use assembly line and continuous flow processes.

It is worth pointing out that this classification of production process is losing its applicability because of the development of flexible manufacturing systems and other hybrid processes. These new processes combine more than one 'traditional' discrete process and there are suggestions that they should be viewed in terms of their complexity which is a composite of two underlying elements: automation degree, and ease of interconnectedness between various operations.

On the whole, the results from hypotheses testing are consistent with theory and intuition.

13.4: Contributions of this Study

This study has made some modest, yet hopefully useful, contributions to the existing body of knowledge in the field from the theoretical, practical, and methodological perspectives. They are discussed below:

- **Theoretical Contributions:**

The contributions of this study are related to the investigations about the structure of strategic manufacturing effectiveness and degrees or stages of its achievement.

The first contribution of the study is to make the structure of the four stages framework explicit. Wheelwright and Hayes (1985) and the few studies which have examined this framework before did not explicitly state the important factors that can affect strategic manufacturing effectiveness. Previous studies, also, did not show how effectiveness can be measured empirically. This study has provided a model that represented strategic manufacturing effectiveness and its antecedents and consequents. It also showed the causal relationships among the factors of effectiveness.

The strength of this integrative model lies in its grounding in extant theory as well as its simplicity of presenting complex constructs in an easy to view and understand model of relationships.

Researchers can use this model in other research settings, like in another population of firms, or it can be adapted to take into effect other factors that have not been included in this study.

It is worth pointing out again the fact that cumulative body of knowledge in the field of manufacturing strategy can only be obtained if researchers choose to build their studies on past research. This issue is critically important for this study since it is largely empirical and therefore had to be developed on sound theoretical ground. The vast practical experiences of Wheelwright and Hayes enabled them to observe the differences in manufacturing capabilities among industrial firms which they managed to attribute to strategic manufacturing effectiveness. Therefore, this study complements the earlier work of Wheelwright and Hayes (1985).

The second contribution of this study is related to the identification of strategic groups. Porter (1985) suggested that the creation and maintenance of competitive advantage are the essence of strategic management. An approach that is used in the business strategy literature to investigate empirically the nature and complexities of competitive advantage is 'strategic groups'.

The concept of strategic groups was introduced by Hunt (1972) to describe the clusters of firms that he observed in the appliance industry. These clusters had significant differences between them in both their characteristics and strategies followed. At the same time he noticed that firms in each cluster followed similar strategies.

Miller and Roth (1994, p. 286) noted the importance of this concept for manufacturing strategy research by stating that:

> 'The determination of homogeneous groups of firms based upon taxonomies has been an important research theme in the general strategic management and organisation literature (Hambrick 1983, Fahey and Christensen 1986, and McGee and Thomas 1986). Most of the research has recognised that firms can be classified by multiple variables into groups which are best characterised by the "gestalt" of the communalities they share (Miller and Friesen, 1977)'

A variety of variables have been used in the business strategy and industrial organisation literature to form taxonomies (Miller and Roth, 1994). Pegels and Sekar (1989) concluded that the most suitable way of forming taxonomies is dependent on what the researcher is trying to achieve.

One of the purposes of this research was to link the four stages framework to the concept of strategic groups. This objective is partially realised by the detection of two groups (out of four). Hambrick (1984) noted, that 'a strategy classification scheme helps bring order to an incredibly cluttered conceptual landscape' (p. 27-28). Therefore, by identifying these two strategic groups whose effectiveness has been shown to relate positively to manufacturing competence, researchers can study in more detail the differences between and within these groups. The advantage of such an effort is that it makes it easy to understand feasible strategic choices that firms exercise in their competitive environment. More research is needed along this path and obviously in order to recognise other stages which were not apparent in this study.

Table 13.2
Comparison of Classificatory Frameworks in Manufacturing Strategy
adapted from Sweeney, 1991

	1	2	3	4
Wheelwright and Hayes	internally neutral	externally neutral	internally supportive	externally supportive
Stobaugh and Telesio	cost-driven strategy	market-driven strategy		technology-driven strategy
Roth and Miller	caretaker	marketeer		innovator
DeMeyer	market oriented group		high performance product group	manufacturing innovators
Edmondson & Wheelwright	quick relief mode		organisational tools mode	competitive edge through manufacturing
Sweeney	quick fix	stretch	catch up	breakthrough

Very few studies have been conducted about strategic groups in manufacturing strategy. Sweeney (1991), as shown in Table 13.2, compared the four stages framework with the frameworks devised by Stobaugh and Telesio (1983), Roth and Miller (1989), DeMeyer (1990), Edmondson and Wheelwright (1989), and Sweeney (1990), and suggested that the four stages of Wheelwright and Hayes (1985) are four generic manufacturing strategies which are comparable with that of other researchers.

This comparison of classificatory frameworks in manufacturing strategy by Sweeney (1991) is a step in the right direction. Future comparative research could build on this study by segregating between the frameworks which are based on manufacturing decisions and choices, like the four stages framework, and others which are conceptualised on the basis of competitive priorities. That is because frameworks based on competitive priorities show distinct manufacturing strategies which are analogous to Porter's business strategies. Whereas frameworks based on manufacturing decisions and choices do not show distinct strategies but degrees of effectiveness. Two such examples in Table 13.2 are the frameworks of Wheelwright and Hayes, and Edmondson and Wheelwright.

- **Practical Contributions:**

The results of this study can be used in conjunction with the analytic tool provided by Hayes *et al.* (1988) and shown in Table 3.3, that gauges the approximate stage a firm is in. There are ten decision categories in this analytic tool. In each category a firm must assess its strengths and weaknesses. For example, with respect to capacity, the firm will examine to know if its capacity lags demand and is capital-request driven or if it matchs or leads demand and is capability driven.

The anlyses from these investigations will provide some clues as to where in the effectiveness continuum the manufacturing function is located. To ascertain the stage of a firm's manufacturing effectiveness, the measures employed in this research can be used. They are the manufacturing improvement programmes which represent materials flow, process technology, resources improvements, quality programmes, information systems, and new product introduction. Higher degree of emphasis on these programmes indicate higher effectiveness.

Having approximated its position, the next task for a firm is to examine why it is in a particular stage. The work done in this research can enable firms to answer this important question.

To find the reasons for the obstacles hindering manufacturing effectiveness, a firm will use the indicators of the antecedent factors to know where the problem(s) might be. For example, it will find out if

- top managers consider manufacturing to be neutral and incapable of influencing competitive success,
- they minimise their involvement with, and thus their perceived dependence on, manufacturing,
- they communicate frequently with the manufacturing managers to understand the problems facing manufacturing and help to solve them,

- manufacturing strategy is formally formulated,
- strategic issues involving manufacturing are tackled by outside experts,
- manufacturing personnels develop thorough analysis when confronted with a major decision,
- manufacturing managers screen decisions to be sure they are consistent with competitive strategy,
- they seek to understand their company's business strategy and the kind of competitive advantage it is pursuing,
- they view their roles as being reactive,
- they involve very late in corporate policy debates,
- they do not express themselves well in corporate policy debates,
- they constantly seek new opportunities related to the present operations,
- operations can be generally characterised as high-risk,
- anticipate the potential of new manufacturing practices and technologies and seek to acquire expertise in them long before their implications are fully apparent.

The above points will guide firms to identify where acute problems might exist. Knowing the obstacles will greatly assist in the determination of suitable solutions.

Firms may want to emphasise more on the indicators that measure the attitude of top managers towards manufacturing and the involvement of manufacturing managers in setting the strategic direction of the firms, since it has been shown in this study that these are the two key factors that have to be present for other factors to develop.

This methodology can be used in a firm with a single manufacturing unit. In such case, it can either be used as a self diagnostic tool as stated above, or as a benchmarking tool to compare itself in different time periods. For multi-unit manufacturing companies, this methodology is also useful in benchmarking the different units with one another in order to track the causes of good and bad effectiveness.

- **Methodological Contributions:**

It has been noted in this research the slow progress of the field of manufacturing strategy because of, among other things, the failure to adopt ideas from the more developed disciplines. In particular, many researchers have complained about the rudimentary methods of analysis used in manufacturing strategy empirical studies. This study has gone into great lengths in addressing this issue. The first stage of rectifying this problem was to follow Churchill's (1979) paradigm in developing measures of constructs. The second stage was using structural equation modelling technique, as implemented in LISREL, to purify the measures. The advantages of using this technique have already been stated in chapter seven.

By providing details of applying Churchill's paradigm and using LISREL, it is hoped that the virtues of methodological rigour in empirical research can be propagated in the field and consequently other researchers can start following these procedures in their own studies.

13.5: Limitations of Study

There are a number of limitations that are associated with this study. The validity and generalisability of the research must be considered within the bounds of these limitations.

- **Using single respondents:**

The use of a single person as the key informant in each firm can contribute to the problem of common method variance which happens when the key informant is lacking in knowledge about the questions he or she is being asked. This lack of knowledge will infect all measures from that person. The possibility of common method variance makes it difficult to isolate correlational relationships between factors which can affect negatively the ability of drawing definitive conclusions from data analyses (Phillips, 1981).

- **Using questionnaire:**

The survey methodology based on questionnaires was used to gather data from single respondents in each manufacturing unit. The questionnaire is known to be susceptible to a variety of errors. For example, because participation in the survey was voluntary, there is a degree of sampling error and response bias. Even though the tests carried out in chapter ten indicated there is no significant response bias, there is still a small element of bias which can affect the generalisability of the results.

- **<u>Using cross sectional design:</u>**

This study used a cross sectional design for data collection which cannot show causality accurately because the process of acquiring effectiveness occurs over time. Therefore, longitudinal design can overcome this problem.

- **<u>Newness and subjectivity of the measures:</u>**

All of the measures used to test the causes of strategic manufacturing effectiveness are new. Such new measures are in need of further purification and extensions. Furthermore, the use of perceptual measures instead of objective ones can influence the validity of results. Future research should emphasise the use of more objective measures if possible.

- **<u>Unit of analysis</u>**

The unit of analysis in this research is the manufacturing plant. Some of the questions in the questionnaire did not specify explicitly the unit of analysis to the potential respondents so that they could answer such questions correctly. One particular example is the number of employees. Some respondents interpreted this as the number of employees in all the company, whereas some responded with the number of employees in a single plant. This question was specifically attempting to measure the sizes of firms and not the plants. Therefore, because the unit of analysis was not specified, the validity of the results could have been affected.

- **Ambiguity of some questions**

Wording of some items in the questionnaire probably made it difficult for some respondents to know exactly what the question is trying to measure. Examples of such items are the questions in Section C of the questionnaire. In this section, the questions should have began with 'you' instead of 'manufacturing manager'.

This ambiguity extends also to the labelling of the scales. For example, with respect to some manufacturing improvement programmes, potential respondents were asked to denote their emphasis on each programme. What was meant by emphasis is if they had carried the improvement programmes out. However, it was possible that some respondents could confuse 'emphasis' with their 'wish list'. Researchers who intend to use this questionnaire must be aware of these limitations.

- **Cross validation of results:**

Cross validation of the results is an important step in empirical study. If the original model is modified to find a higher degree of correspondence between constructs and their measures (better model fit for the data), then cross-validation is necessary. However, cross-validation may also be carried out even when the data fits the model the first time (Diamantopoulos, 1994). That is because the fit might be specific to the data set and thus cannot be repeated for other samples from the population (Backhaus *et al.* 1989).

In order to cross-validate, a new sample must be used. There are two ways to get this sample. The ideal way is to collect data again from the same population under study. However in practice, the way it is accomplished is through dividing the original sample into two parts. As Yi and Nassem (1992) explained

> "one part is used for deriving the model, while the other is used for evaluating the derived model. In this sense, cross-validation simulates prediction of an independent sample" (p. 409).

Neither of these two ways was possible for this research. Collecting a new sample from the same population under study within a short period of time from the first collection effort was not possible, since it would have been very difficult to get the commitment of the firms again. Dividing the sample into two halves was contemplated, but this idea was also not possible because this exercise would have reduced sample size in half. The method that is used to develop the model is structural equation modelling, and it requires large sample sizes to be able to draw any meaningful conclusions from the results.

13.6: Directions for Future Research

This research is a first step in the development of a more complex model that explicitly defines factors of strategic manufacturing effectiveness in a theoretical network. And while it has attempted to answer some research questions on this subject, it has also generated others which can form the basis for further studies in the future. The limitations cited above provide some directions for future research. For example, future research needs to use better research designs like employing more than one key informant in order to overcome the problem of common method variance, and using longitudinal research design and objective measures of various factors in the strategic manufacturing effectiveness framework which will contribute to the understanding of how it is acquired. The newness of the measures used in this study requires that they are reviewed and adjusted in future studies. That is specially important because of the marginality of model fit.

It appears also that there are additional variables that need to be included in the framework. This conclusion is reinforced by the fact that there are correlated error terms in the model. That usually signals the fact that some factors have not been explicitly included in the model. This is especially true if the theory under investigation is not developed enough for complete specification (Hughes *et al.*, 1986). Future research may address this deficiency by identifying those variables that provide more explanations to the complex relationships in the framework.

Overcoming the limitations of this study is just one avenue of future research. Some other directions are detailed below:

- **<u>Examining each factor of effectiveness separately:</u>**

One important venue of research is the examination of each individual factor that collectively constitute strategic manufacturing effectiveness.

It is worthwhile looking at how, for example, the choice of process technology is affected by the attitude of top managers and the involvement of manufacturing managers in setting the strategic direction of the firm.

Past research has pointed out that there is the need for a clear perspective on process technology in general, and automation in particular. Automation might not always be the best or even the right path to take. A practical example is the two plants of Toro, a consumer company in Wisconsin and Minnesota, USA. Both plants compete on delivery timeliness and speed. To improve this capability they considered automation of their manufacturing processes. However, the Minnesota plant did not automate but instead managed to get considerable improvements in the delivery capability by tackling basic problems in its existing processes (Appliance Manufacturer, 1993). This case supports the views of Slack *et al.* (1995) who noted that

> 'Technology can be seen as a panacea for all the operation's ills, a 'technology fix' which avoids more fundamental problems. If the methods and processes are themselves flawed, technology will just speed up the problems not solve them' (p. 329).

When automation is chosen, it has to be viewed from a clear perspective, otherwise its benefits might not be realised. A case in point is the General Electric Co. (GE) plant in Charlottesville, Virginia. This plant produces programmable logic controllers, computer numerical controls, and other types of automation equipment. The management of the plant relied heavily on automation. That resulted in the company loosing market share and forced it to merge with its once fierce rival Fanuc Ltd., and a new management team were brought in which revamped the plant's vision on automation by making it the servant of the production process and not the reverse (Burrows, 1991).

On the other hand, Allen-Bradley, a world-wide manufacturer of industrial automation controls and systems, had clear objectives when it opened its EMS1 facility in 1992. At the time, EMS1, which stands for electronic manufacturing strategy, was one of one of the most advanced electronics manufacturing operations in the world. The objectives of the facility were to achieve high product quality, reduce time to market, and extend manufacturing capacity to handle existing and new products. These objectives formed the basis for the design and running of the facility (Blass, 1992).

The examples on process technology and automation are just one area of many that are worth examining in future research.

- **Extending the concept of manufacturing competence:**

Examination of the constituents of manufacturing performance has not been the major focus of this study. That is because the measures of performance, which are the competitive capabilities, have had extensive treatment in the literature. The efforts culminated in the concept of manufacturing competence.

However, Vickery (1991) noted that manufacturing competence only 'provides a "snapshot" of the performance or effectiveness of manufacturing with respect to its current set of competitive priorities'. So, it can be argued that the frameworks reviewed in chapter four can be extended to cover the domain of the manufacturing competence construct which was defined by Cleveland *et al.* (1989) as 'the preparedness, skill, or capability that enables manufacturers to prosecute a product-market specific business strategy'. The argument for extending the conceptualisation of manufacturing competence is built around two points:

- Cleveland *et al.* (1989), Kim and Arnold (1993) and Vickery *et al.* (1993) did not operationalise the definition fully. What was operationalised is the level of capabilities achieved. However, their frameworks do not give any indication of how 'prepared' manufacturing is.
- To prosecute a product-market specific business strategy requires capabilities that are sustainable.

So in order to conceptualise a better representation of manufacturing competence, it is important to include not only how much has been achieved at a certain point in time, but also how prepared a firm is to achieve the targeted performance, and how competitors are catching up. This is analogous to a race where a participant has to worry not only about how well he or she is doing at a particular moment, but also how difficult it is to finish the remaining distance, and how competitors are catching up. These points can be detailed as follows:

1. Manufacturing competence is a relative measure of manufacturing performance (Cleveland *et al.*, 1989). It gives the assessment of

competence of one manufacturer relative to others. Since the importance of capabilities changes over time, a manufacturer has to upgrade continuously its competencies to stay competitive. In this context, Hill (1989) suggested the notions of order winning criteria (OWC) and order qualifying criteria (OQC). To qualify for an order, a firm must meet the OQC, and to be in contention of winning orders, it has to meet the OWC for its industry. Hill also noted that, over time, OWC can change to OQC. The reason is that companies are always replicating the capabilities of one another, and so whatever an advantage a firm has is not sustainable for very long periods of time. Consequently, sustainability of capabilities can be an important aspect of competence.

2. For firms that have not yet reached their targeted level of performance, there is still scope for improvement. The potential for achieving this unfulfilled performance is dependent on the easiness or difficulty of achieving capabilities. If, for example, a firm finds it difficult to develop certain capabilities, then its preparedness for achieving higher performance will be low.

These points are endorsed by the view of Coyne (1986) who stated that one of the conditions that make a competitive advantage meaningful in strategy is that 'the difference in important attributes and the capability gap (superior performance relative to other firms) can be expected to endure over time'. This statement also implies that if a firm is at a disadvantage with respect to the capability gap, it must have the potential to fill it in order to neutralise its competitors' advantage.

The concept of manufacturing competence can be extended still further by incorporating the model of cumulative competitive capabilities. Nakane (1986) noted that not only are some successful manufacturers competing on all competitive priorities but they also follow specific sequence in their quest to build capabilities. The sequence that he observed starts with quality followed by dependability, cost, and flexibility respectively. Ferdows and De Meyer (1990) had somewhat similar observations for their model that they called 'the sand cone model'.

Another issue which can influence the measurement of manufacturing competence is the inherent trade-offs among competitive capabilities. Even though it has been stated earlier that there are firms which beat their competitors in all aspects of competition, they still have to make trade-offs. As New (1992) explained, 'while several of the conventional trade-offs have been eliminated, there are just as many which remain, while others have been affected in degree but not in substance' (p. 28). Therefore, the process by which firms choose their competitive priorities must be taken into account when manufacturing competence is measured and evaluated.

If the arguments presented above are taken into account, then it can be hypothesised that along with the level of achieved performance, there are probably four more dimensions that can extend our understanding of manufacturing competence. These are the sustainability of achieved performance, the potential for achieving unfulfilled performance, the order of capability building, and the strategic trade-offs of capabilities.

The arguments for extending the concept of manufacturing competence indicate that there is quite a scope for improving this important concept, and hence the frameworks reviewed might not fully capture the 'true' manufacturing competence. Cleveland *et al.* (1989) realised this point from the beginning by stating that there are other ways to operationalise this concept.

13.7: Summary

Even though the framework of Wheelwright and Hayes (1985) is widely accepted by researchers as a fair representation of the stages of strategic manufacturing effectiveness, it has remained mostly in the theoretical domain. There was little empirical research to lend it support. This research, therefore, set out to test this framework by incorporating factors that measure it directly and both its causes and outcomes. The results of this effort and conclusions reached were discussed in this chapter.

The central assertion that can be made from this research is that consistent attention to the antecedent factors that affect strategic manufacturing effectiveness, with more emphasis on the two key factors, is necessary for the attainment of effectiveness in manufacturing.

Also, increased attention to the issues of instrument validation can contribute significantly to the field of manufacturing by moving it forward in the right direction through the development of streams of replicated studies and purified concepts. This is one of the few studies to have emphasised the development of models and the conduction of validity and reliability tests using the powerful LISREL methodology which has been used extensively in many branches of the social sciences.

This research has provided some answers, albeit tentative ones, to some important questions, but it also raised many others that need to be addressed. The research findings suggest that further study of the factors of strategic manufacturing effectiveness holds promise for greater insight in its development. Future efforts can start by attempting to replicate the results of this study in other samples.

Finally, in the current intensity and complexity of competition that faces manufacturing firms all over the globe, there is a need for a greater understanding of how manufacturing effectiveness is obtained. This research has shed some light into this matter, and it is hoped that it will generate interest from both researchers and practitioners who can rectify its shortcomings and demonstrate its usefulness.

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Appendices

Appendix A: The Questionnaire

Appendix B: Checking for Multivariate Outliers

Appendix C: General Models of LISREL

Appendix D: Three and Four Cluster Solutions

Appendix A: The Questionnaire

I. The Cover Letter

{ ADDRESS}

Dear Sir,

The enclosed questionnaire is part of a study which is being conducted in the University of Nottingham to investigate the role that manufacturing can play in gaining a competitive advantage for a firm in its marketplace. Researchers and practitioners have pointed that this role, on one hand, can be trivial where manufacturing offers very little support to the firm's success. However, manufacturing, on the other hand, has the potential to contribute significantly to the competitive advantage of the firm.

Factors such as the emphasis on specific set of manufacturing choices and the roles and attitudes of both senior and manufacturing managers have been cited as some of the indicators of the role of manufacturing. Unfortunately, little research has been carried out to investigate how these factors combine to give manufacturing a greater role to play in a firm. Also, the linkage between the strategic role of manufacturing and performance has not been thoroughly explored. This questionnaire has been designed to address these issues.

Your support is vital to the success of this study, and we hope that your firm will participate in this important project. Since most of the questions are concerned with the manufacturing function, we would like this questionnaire to be filled by the manufacturing manager or the person in charge of manufacturing in your firm or one of its subsidiaries.

We urge you to complete the questionnaire and send it back as soon as you can. It will take less than 15 minutes to complete. A self-addressed reply envelope is provided for your convenience. Stamp is not needed to mail back the questionnaire.

All information that you provide will be held in strict confidence and only myself and my supervisor, Dr. Vic Gilgeous, will have access to this information. We would like to assure you that the results obtained from this questionnaire will be aggregated prior to analysis, and so there will be no remarks to names of companies and respondents.

In order to get a summary of the results obtained from this study, please write your name and address in the space provided in the first page of the questionnaire.

If you have any questions regarding the questionnaire, please contact me at 0115-9514053. Thank you for your cooperation.

Sincerely yours,

A. N. Al-Rasby
Department of Manufacturing
Engineering & Operations Management
University of Nottingham
Nottingham NG7 2RD

II. The Follow-up Letter

{ ADDRESS}

Dear Sir,

Five weeks ago, I mailed you a questionnaire which is part of a study being undertaken in the University of Nottingham to investigate the role that manufacturing can play in gaining a competitive advantage for a firm in its marketplace. Researchers and practitioners have pointed that this role, on one hand, can be trivial where manufacturing offers very little support to the firm's success. However, manufacturing, on the other hand, has the potential to contribute significantly to the competitive advantage of the firm.

Factors such as the emphasis on specific set of manufacturing choices and the roles and attitudes of both senior and manufacturing managers have been cited as some of the indicators of the role of manufacturing. Unfortunately, little research has been carried out to investigate how these factors combine to give manufacturing a greater role to play in a firm. Also, the linkage between the strategic role of manufacturing and performance has not been thoroughly explored. This questionnaire has been designed to address these issues.

Up to now, I have not yet received your completed questionnaire. I have included another copy of the questionnaire in case that you have not received my earlier letter.

Since this questionnaire has been sent to a representative sample of manufacturing firms, every response is significant and the usefulness of this study is very much dependent on receiving your response. So please complete the questionnaire as soon as you can. It will take less than 15 minutes to complete. A self-addressed reply envelope is provided for your convenience. Stamp is not needed to mail back the questionnaire.

In order to get a summary of the results obtained from this study, please write your name and address in the space provided in the first page of the questionnaire.
If you have any queries, please contact me at 0115 9514053.
Thank you for your co-operation.

Sincerely yours,

A. N. Al-Rasby
FREEPOST (NG6649)
Department of Manufacturing
Engineering & Operations Management
University of Nottingham
Nottingham NG7 IBR

III. The Survey Instrument

Questionnaire Survey

University of Nottingham
Department of Manufacturing Engineering and Operations Management

If you wish to receive a summary of the results, please provide your name, job title, and the name and address of the company. This information will be kept confidential.

1. Name of Respondent

----

2. Position of Respondent

----

3. Name and Address of the Company

Section A:
Company Details

1. Please state the number of full-time employees:
   1. Shopfloor............. 2. Managers............. 3. Staff.............

2. What is the "average" age of your production equipment:
   1. less than 5 years old ☐
   2. 5 to 15 years old ☐
   3. 15 to 30 years old ☐
   4. older than 30 years ☐

3. Please indicate the proportion of products that are:
   1. made as standard products (to stock).......................per cent
   2. made to customer specification (to order))............... per cent

4. Please indicate the dominant type of manufacturing process used:
   1. job shop ☐
   2. batch ☐
   3. assembly line ☐
   4. continuous flow ☐

5. Please indicate the business strategy that your company follow by ticking the appropriate box:
   1. competing on cost ☐
   2. competing through other means ☐
   3. competing on both cost and differentiation ☐
   4. no particular strategy is followed ☐

Section B:

Please indicate the extent of emphasis on the following manufacturing choices in your company by circling the appropriate response.

Manufacturing Choices		**No emphasis**		**Moderate emphasis**		**Great emphasis**
1.	Manufacturing lead time reduction	1	2	3	4	5
2.	Just-in-Time (JIT)	1	2	3	4	5
3.	Implementing Flexible manufacturing systems	1	2	3	4	5
4.	Implementing CAD/CAM	1	2	3	4	5
5.	Developing new processes for new products	1	2	3	4	5
6.	Developing new processes for old products	1	2	3	4	5
7.	Sourcing equipment and technology from outside suppliers.	1	2	3	4	5
8.	Helping suppliers to solve problems	1	2	3	4	5
9.	Capacity expansion	1	2	3	4	5
10.	Reconditioning of physical facilities	1	2	3	4	5
11.	Reducing the size of manufacturing work force	1	2	3	4	5
12.	Plant relocation or Closing plants	1	2	3	4	5
13.	Management training	1	2	3	4	5
14.	Worker training	1	2	3	4	5
15.	Worker safety	1	2	3	4	5
16.	Giving workers a broad range of tasks	1	2	3	4	5
17.	Statistical quality control	1	2	3	4	5
18.	Vendor quality	1	2	3	4	5
19.	Zero defects	1	2	3	4	5
20.	Quality circles	1	2	3	4	5
21.	Preventive maintenance	1	2	3	4	5
22.	Employing detailed measurements and controls of operating performance.	1	2	3	4	5
23.	Incorporating nonfinancial considerations in the capital budgeting process.	1	2	3	4	5
24.	Integrating systems across the firm	1	2	3	4	5
25.	Integrating systems within manufacturing	1	2	3	4	5
26.	Improving new product introduction capability	1	2	3	4	5

Section C:

The following statements measure your involvement, as the manufacturing manager, in setting the strategic direction of the firm. Please indicate the extent of your agreement with these statements by circling the appropriate response.

Involvement of Manufacturing Managers	**Strongly agree**		**Neither agree/ nor disagree**		**Strongly disagree**
1. Manufacturing manager seeks to understand the company's business strategy and the kind of competitive advantage it is pursuing.	1	2	3	4	5
2. Manufacturing manager views his role as being only reactive to the demands placed on the production system.	1	2	3	4	5
3. Manufacturing manager involves very late in corporate strategy debates.	1	2	3	4	5
4. Manufacturing manager does not explain effectively manufacturing strategy issues in corporate policy debates.	1	2	3	4	5
5. Manufacturing manager spends most of his time in dealing with day-to-day operating issues.	1	2	3	4	5

Section D:

The following statements measure the attitude of top managers towards manufacturing. Please indicate the extent of your agreement with these statements by circling the appropriate response.

Attitude of Top Managers		Strongly agree		Neither agree/ nor disagree		Strongly disagree
1.	Top managers consider manufacturing to be incapable of influencing competitive success.	1	2	3	4	5
2.	Top managers minimise their involvement with manufacturing.	1	2	3	4	5
3.	Top managers encourage manufacturing to follow industry practice in matters regarding the work force, equipment purchases, and capacity additions.	1	2	3	4	5
4.	Top managers view economies of scale related to the production rate as the most important source of manufacturing efficiency.	1	2	3	4	5
5.	Top managers regard resource allocation decisions as the most effective means of addressing the major strategic issues in manufacturing.	1	2	3	4	5
6.	Top managers communicate frequently with the manufacturing manager to understand the problems facing manufacturing and help to solve them.	1	2	3	4	5

Section E:

Please indicate the extent of emphasis on the following actions in your company by circling the appropriate response.

Manufacturing Actions		**No emphasis**		**Moderate emphasis**		**Great emphasis**
1.	Developing thorough analysis when confronted with a major decision.	1	2	3	4	5
2.	Screening decisions to be sure that they are consistent with the organisation's competitive strategy.	1	2	3	4	5
3.	Seeking new opportunities related to the present operations.	1	2	3	4	5
4.	Taking some risks when making decisions.	1	2	3	4	5
5.	Anticipating the potential of new manufacturing practices and technologies and seeking to acquire expertise in them long before their implications are fully apparent.	1	2	3	4	5
6.	Interactive development of business, manufacturing, and other functional strategies.	1	2	3	4	5
7.	Interactions between manufacturing and other functions to facilitate product design, field service, and sales training.	1	2	3	4	5
8.	Transfer of 'know-how' between manufacturing and other functions.	1	2	3	4	5
9.	Developing manufacturing strategy.	1	2	3	4	5
10.	Getting the help of outside experts to tackle strategic issues involving manufacturing.	1	2	3	4	5

Section F:

Please circle the most appropriate response that describes the relative importance of each of the manufacturing capabilities listed below.

THE CAPABILITY TO:	Not important		Moderately important		Extremely important
1. Customise products to customer needs	1	2	3	4	5
2. Make rapid volume changes	1	2	3	4	5
3. Make rapid product mix changes	1	2	3	4	5
4. Introduce new products quickly	1	2	3	4	5
5. Provide fast delivery of products	1	2	3	4	5
6. Deliver products on time as promised	1	2	3	4	5
7. Offer reliable products	1	2	3	4	5
8. Manufacture with consistently low defect rates	1	2	3	4	5
9. Make rapid design changes	1	2	3	4	5
10. Manufacture with lower cost than competitors	1	2	3	4	5
11. Provide effective after-sales services	1	2	3	4	5
12. Offer broad line of products	1	2	3	4	5
13. Make products easily available (broad distribution)	1	2	3	4	5
14. Provide high performance products	1	2	3	4	5
15. Provide product support effectively	1	2	3	4	5

Section G:

Please circle the most appropriate response that describes the performance of your firm relative to your competitors in each of the manufacturing capabilities listed below.

THE CAPABILITY TO:		Substantially weaker		Industry average		Substantially stronger
1.	Customise products to customer needs	1	2	3	4	5
2.	Make rapid volume changes	1	2	3	4	5
3.	Make rapid product mix changes	1	2	3	4	5
4.	Introduce new products quickly	1	2	3	4	5
5.	Provide fast delivery of products	1	2	3	4	5
6.	Deliver products on time as promised	1	2	3	4	5
7.	Offer reliable products	1	2	3	4	5
8.	Manufacture with consistently low defect rates	1	2	3	4	5
9.	Make rapid design changes	1	2	3	4	5
10.	Manufacture with lower cost than competitors	1	2	3	4	5
11.	Provide effective after-sales services	1	2	3	4	5
12.	Offer broad line of products	1	2	3	4	5
13.	Make products easily available (broad distribution)	1	2	3	4	5
14.	Provide high performance products	1	2	3	4	5
15.	Provide product support effectively	1	2	3	4	5

THANK YOU FOR YOUR COOPERATION

Appendix B:

Checking for Multivariate Outliers

The tables below and in the next pages show Mahalanobis distances. and significance levels for each case in the sample of firms under study. As explained in chapter ten, Mahalanobis distance measures the distance in multidimensional space between each case and the mean of all cases. The longer the distance between a case and the mean of cases, the more likely that this case is an outlier. By using the chi-square statistic, a threshold value for significance level of .001 is taken as a designation for an outlier.

From these tables, it is apparent that all cases except one have a significance level above .001, with the one exception having a value of .0009 which is very close to the threshold value. Therefore, it can be concluded from this test that there are no explicit outliers in the sample.

Case No.	Mahalanobis Distance	Significance
1	24.63	.4833
2	24.07	.5154
3	28.39	.2901
4	15.73	.9226
5	30.40	.2095
6	22.08	.6313
7	18.06	.8399
8	36.18	.0689
9	15.80	.9206
10	23.17	.5676
11	25.37	.4419
12	19.61	.7669
13	32.17	.1531
14	19.81	.7565
15	42.91	.0143

Case No.	Mahalanobis Distance	Significance
16	22.40	.6128
17	18.48	.8212
18	30.85	.1941
19	34.14	.1050
20	14.96	.9423
21	23.18	.5673
22	20.68	.7105
23	29.67	.2370
24	14.41	.9542
25	22.31	.6181
26	19.87	.7536
27	15.44	.9306
28	22.01	.6354
29	24.46	.4931
30	29.07	.2610
31	14.54	.9515
32	18.49	.8208
33	48.26	.0035
34	16.88	.8861
35	22.90	.5832
36	22.81	.5887
37	19.20	.7873
38	36.87	.0594
39	20.81	.7034
40	28.03	.3064
41	18.86	.8037
42	35.15	.0855
43	27.31	.3406
44	12.05	.9861
45	31.84	.1628
46	19.79	.7577
47	28.08	.3042
48	21.81	.6466
49	25.15	.4540
50	28.20	.2986
51	21.56	.6609
52	25.08	.4582
53	27.63	.3250
54	16.00	.9149
55	10.68	.9944
56	33.36	.1223
57	18.03	.8410
58	22.14	.6278
59	15.04	.9404
60	27.85	.3149
61	29.98	.2249
62	34.80	.0918
63	33.15	.1273
64	30.15	.2187
65	33.63	.1160
66	24.41	.4957
67	17.23	.8732

Case No.	Mahalanobis Distance	Significance
68	26.03	.4059
69	17.63	.8578
70	7.85	.9996
71	13.21	.9739
72	34.26	.1024
73	35.85	.0739
74	14.23	.9575
75	29.83	.2308
76	20.40	.7253
77	19.06	.7941
78	37.23	.0549
79	21.56	.6611
80	23.08	.5730
81	27.14	.3487
82	15.98	.9154
83	41.65	.0196
84	20.75	.7064
85	28.29	.2945
86	26.07	.4037
87	41.48	.0204
88	18.74	.8095
89	18.73	.8099
90	28.74	.2748
91	21.75	.6503
92	18.63	.8143
93	18.76	.8086
94	31.05	.1873
95	24.28	.5032
96	12.59	.9811
97	32.74	.1378
98	10.47	.9952
99	25.65	.4263
100	22.58	.6023
101	27.79	.3177
102	18.20	.8337
103	35.93	.0727
104	31.40	.1762
105	35.55	.0788
106	20.93	.6964
107	21.12	.6857
108	23.26	.5625
109	26.56	.3781
110	41.50	.0203
111	35.12	.0861
112	22.44	.6105
113	14.68	.9486
114	28.20	.2988
115	28.58	.2820
116	40.36	.0268
117	21.17	.6833
118	26.41	.3860
119	28.65	.2789

Case No.	Mahalanobis distance	Significance
120	21.64	.6566
121	21.34	.6736
122	12.96	.9770
123	33.39	.1217
124	19.66	.7642
125	33.40	.1215
126	24.65	.4822
127	15.85	.9192
128	23.20	.5661
129	26.00	.4077
130	12.32	.9838
131	23.61	.5417
132	30.05	.2224
133	31.11	.1855
134	44.53	.0095
135	21.09	.6875
136	26.72	.3700
137	23.83	.5295
138	26.72	.3700
139	38.67	.0398
140	11.98	.9868
141	18.74	.8096
142	38.35	.0427
143	19.53	.7710
144	12.86	.9781
145	35.65	.0770
146	38.62	.0402
147	19.67	.7641
148	20.90	.6983
149	41.02	.0229
150	38.37	.0426
151	15.52	.9285
152	20.28	.7320
153	28.84	.2707
154	15.86	.9190
155	26.09	.4028
156	22.84	.5870
157	27.86	.3145
158	19.19	.7878
159	18.63	.8143
160	14.38	.9547
161	20.64	.7126
162	14.29	.9565
163	32.84	.1350
164	24.49	.4913
165	23.49	.5488
166	23.81	.5306
167	13.16	.9745
168	21.58	.6599
169	9.07	.9985
170	9.27	.9982
171	21.85	.6447

Case No.	Mahalanobis distance	Significance
172	19.15	.7900
173	23.58	.5439
174	22.27	.6201
175	17.03	.8805
176	22.99	.5780
177	27.48	.3324
178	16.00	.9147
179	23.31	.5593
180	26.49	.3819
181	20.90	.6983
182	30.28	.2138
183	17.56	.8604
184	18.45	.8227
185	18.95	.7996
186	22.66	.5977
187	45.07	.0082
188	15.90	.9178
189	34.70	.0938
190	26.60	.3763
191	26.66	.3732
192	31.21	.1823
193	15.30	.9340
194	15.75	.9221
195	33.05	.1298
196	28.87	.2696
197	16.53	.8982
198	15.69	.9237
199	12.99	.9766
200	27.55	.3289
201	18.94	.8002
202	28.54	.2835
203	15.23	.9359
204	44.76	.0089
205	38.24	.0438
206	32.81	.1359
207	24.13	.5119
208	18.30	.8295
209	21.67	.6547
210	21.68	.6542
211	23.08	.5730
212	13.74	.9662
213	52.82	.0009
214	23.09	.5721
215	12.52	.9819
216	18.31	.8289
217	20.72	.7079
218	27.49	.3320
219	36.39	.0658
220	18.47	.8218
221	29.59	.2400
222	36.23	.0682
223	9.67	.9975

Case No.	Mahalanobis distance	Significance
224	15.22	.9362
225	17.10	.8783
226	25.69	.4242
227	17.66	.8566
228	20.79	.7045
229	30.26	.2147
230	21.79	.6479
231	25.18	.4524
232	27.71	.3215
233	32.20	.1524
234	12.10	.9857
235	29.44	.2459
236	33.60	.1167
237	24.91	.4674
238	18.00	.8425
239	34.81	.0917
240	33.16	.1270
241	33.41	.1212
242	43.97	.0109
243	30.40	.2095
244	23.07	.5737
245	35.57	.0784
246	27.97	.3092
247	17.61	.8584
248	35.14	.0856
249	24.58	.4858
250	23.93	.5232
251	20.03	.7454
252	23.35	.5569
253	27.63	.3252
254	21.26	.6781
255	14.34	.9556
256	20.76	.7060
257	24.73	.4774
258	31.45	.1746
259	35.66	.0768
260	41.70	.0193
261	15.16	.9375
262	28.02	.3070
263	28.24	.2968
264	33.79	.1125
265	28.56	.2827
266	26.11	.4017
267	15.40	.9316
268	22.58	.6021
269	27.39	.3369
270	28.88	.2691
271	41.36	.0210
272	33.65	.1156
273	32.13	.1544
274	34.02	.1074
275	33.19	.1264

Case No.	Mahalanobis distance	Significance
276	23.39	.5546
277	17.89	.8472
278	11.16	.9921
279	20.07	.7432
280	26.15	.3998
281	16.09	.9120
282	17.20	.8744
283	42.50	.0159
284	35.38	.0816
285	21.24	.6789
286	19.38	.7784
287	31.77	.1647
288	29.70	.2355
289	27.34	.3391
290	13.06	.9757
291	32.64	.1404
292	19.99	.7476
293	15.16	.9377
294	26.31	.3915
295	32.03	.1572

Appendix C:

General Models of LISREL

The Lisrel programme estimates three basic equations, two for measurement models and the third for a structural model as shown in the figure below.

For a model to be analysed through structural equation modelling, it must comprise at least one exogenous latent variable, one that is not causally affected by any other latent variable in the model, and at least one endogenous latent variable, one directly affected by exogenous or other endogenous latent variables if there happens to be more than one endogenous latent variable in the model (Hayduk, 1987). These three equations form the basis for reliability and validity assessments, and model development as explained in chapter 11.

General Structural Equation Model of Lisrel
Adapted from Hayduk (1987)

The structural model:

$$\eta = B\eta + \Gamma\xi + \zeta$$

where η = vector of endogenous latent variables
ξ = vector of exogenous latent variables
B, Γ = matrices of structural coefficients (factor loadings).
ζ = vector of errors in the measurement model

The measurement model for endogenous variables:

$$y = \Lambda_y \eta + \varepsilon$$

where y = vector of observed endogenous indicators
Λ_y = matrix of structural coefficients
η = a vector of endogenous latent variables
ε = vector of errors in the measurement model

The measurement model for exogenous variables:

$$X = \Lambda_x \xi + \delta$$

where X = vector of observed exogenous indicators
Λ_x = matrix of structural coefficients (factor loadings).
ξ = vector of exogenous latent variables
δ = vector of errors in the measurement model

Appendix D:

Three and Four Cluster Solutions

I. Three -Cluster Solution

a. Initial Cluster Centres

Cluster	Std1	Std2	Std4	Std5	Std6	Std7
1	4.0074	3.6360	4.0515	3.5574	4.2647	4.6691
2	3.8873	3.1901	4.0235	3.3972	3.6268	3.1690
3	2.8636	2.6392	3.1061	2.5500	3.1250	3.0341

b. Final Cluster Centres

Cluster	Std1	Std2	Std4	Std5	Std6	Std7
1	4.0574	3.6680	4.0628	3.5803	4.3197	4.7377
2	3.7553	3.1968	3.9681	3.3830	3.5957	3.3723
3	2.8481	2.5981	3.0549	2.4633	3.1329	2.9367

c. Average Cluster Centres for Each Cluster

Cluster	Average
1	4.07
2	3.54
3	2.83

d. Significance Testing of Differences Between Cluster Centres

Variable	Cluster Mean Square	Degrees of Freedom	Error Mean Square	Degrees of Freedom	F Value	Prob.
Std1	36.0210	2	.572	292.0	62.9270	.000
Std2	27.5279	2	.391	292.0	70.2995	.000
Std4	27.2692	2	.364	292.0	74.8316	.000
Std5	31.7860	2	.438	292.0	72.5294	.000
Std6	35.8898	2	.553	292.0	64.8803	.000
Std7	91.6099	2	.583	292.0	157.1148	.000

e. Number of Cases in Each Cluster

Cluster	Cases
1	122
2	94
3	79

II. Four -Cluster Solution

a. Initial Cluster Centres

Cluster	Std1	Std2	Std4	Std5	Std6	Std7
1	3.0714	3.0119	3.4444	2.5778	3.9921	4.2698
2	4.3571	3.7940	4.2930	3.8681	4.4725	4.6154
3	3.7808	3.2774	3.8539	3.4904	3.2877	3.7945
4	3.0441	2.6324	3.2500	2.6500	3.1471	2.3676

b. Final Cluster Centres

Cluster	Std1	Std2	Std4	Std5	Std6	Std7
1	3.0645	3.0121	3.4355	2.5677	3.9758	4.2581
2	4.3407	3.7775	4.2967	3.8703	4.4890	4.6264
3	3.7973	3.2939	3.8514	3.4838	3.2905	3.7973
4	3.0441	2.6324	3.2500	2.6500	3.1471	2.3676

c. Average Cluster Centres for Each Cluster

Cluster	Average
1	3.39
2	4.23
3	3.59
4	2.85

c. Significance Testing of Differences Between Cluster Centres

Variable	Cluster Mean Square	Degrees of Freedom	Error Mean Square	Degrees of Freedom	F Value	Prob.
Std1	30.3937	3	.508	291.0	59.7572	.000
Std2	18.2697	3	.393	291.0	46.3964	.000
Std4	17.0147	3	.377	291.0	45.0519	.000
Std5	30.7017	3	.341	291.0	89.8489	.000
Std6	31.0232	3	.481	291.0	64.3756	.000
Std7	71.5140	3	.477	291.0	149.7854	.000

d. Number of Cases in Each Cluster

Cluster	Cases
1	62
2	91
3	74
4	68