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THE DELIVERY RELIABILITY OF UK MANUFACTURING PLANTS: AN EMPIRICAL STUDY

SCHOOL OF MANAGEMENT

Ph.D. THESIS

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1998 - 1999

MAREK GREGORY SZWEJCZEWSKI

The Delivery Reliability of UK Manufacturing Plants: An Empirical Study

Supervisor: Professor Colin New

March 1999

ABSTRACT

Delivery reliability is an important factor that customers consider when selecting their suppliers. It is also an important component of manufacturing strategy. With quality consistency now being taken for granted in some market sectors delivery reliability is one of the few variables a manufacturing company can compete on.

The operations management literature suggests a number of variables that impact plant delivery reliability, but offers little empirical research evidence to substantiate the claims made, this research re-addresses this imbalance.

The research examined the nature of the relationship between delivery reliability and a series of variables. In particular the research examined the relationship between the plant's delivery reliability and the following variables: part complexity, customisation, supplier delivery reliability, management focus and performance measurement focus.

The research made a number of contributions. Firstly, the research found a significant negative relationship existed between the proportion of customised products and delivery reliability. The results indicate that as the proportion of customised products increases so the level of plant delivery reliability declines. Secondly, the research found that plants that supplied mainly demanding customers had high levels of delivery reliability. Whilst those plants that supplied some or no demanding customers had low levels of plant delivery reliability. The research also found that supplier delivery reliability was positively related to plant delivery reliability. The results suggested that as supplier delivery reliability improves so does plant delivery reliability. The research results pointed to the fact that the focus of the management team on delivery reliability was also related to delivery reliability. The plants where the management team was focused on delivery reliability also had high levels of delivery reliability.

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CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

This thesis describes research into the issue of plant delivery performance and more specifically delivery reliability. Delivery reliability is an important factor that customers consider when selecting their suppliers. Customers have over the years become more demanding with regard to delivery reliability; many now expect consistent on-time. In some market sectors the failure to deliver on-time can have a dramatic financial impact on a company. For example, the failure to delivery on-time to an automotive car assembly plant can mean a loss of contract to supply and a damaging reputation for poor delivery.

Modern manufacturing plants tend to manufacture products with high bought out content and operate with low inventories. This means that plants are more dependent on suppliers providing high levels of delivery reliability.

Delivery reliability is also an important component of manufacturing strategy, it helps manufacturing companies win orders in the market place. With quality consistency now being taken for granted in some markets, delivery reliability is one of the few variables a manufacturing company can compete on.

Although delivery reliability is such an important issue, it is actually an area in which there has been little research. Consequently, there is considerable scope for investigation to be carried out and the opportunity to make a contribution to our understanding of this important issue.

This chapter starts with an explanation of the concept of delivery performance. It then goes on to discuss the importance of delivery performance both as a key manufacturing strategy variable and in terms of its relative importance to industry. The contribution of this research to the knowledge base of operations management is examined. The chapter then goes onto to discuss the research design and methodology used. Finally, the chapter ends with an overview of the general structure of the thesis.

1.1 BACKGROUND

To provide some background to this subject let us start with a definition of delivery performance. Delivery performance has as New and Sweeney (1984) point out, two components:

- Product availability
- Delivery reliability

Product availability is the lead time quoted to the customer - it is the length of time between the placing of the order (by the customer) and the planned delivery to the customer of that order. Delivery reliability is the degree of accuracy in the delivery i.e. the difference between the date (and time) that the item was actually delivered and the due date (and time) that was agreed with the customer.

Both elements of delivery performance are important to the customer (New & Sweeney, 1984; Maruchek & McClelland, 1986). Initially, when the customer asks for a delivery quotation it is necessary to offer a competitive lead time to win the order - hence we have the concept of product availability. However, once the order has been placed, it is necessary to ensure good delivery reliability. Quoting a very competitive lead time to a customer may initially win you the order (by offering good product availability), but then failing to deliver the order on time (having poor delivery reliability) is likely to lose you future business with that customer. Maruchek and

McClelland contend that when price and quality are equal, customers will choose the supplier who promises the shortest lead times and will continue to deal with that supplier as long as the promised delivery dates are reliable. Both elements of delivery performance are therefore important in the customer-supplier relationship.

New & Sweeney contend that the functions of the two elements of delivery performance are quite different. The function of product availability is to gain orders at the expense of competitors (i.e. to achieve short-term market share), while the function of delivery reliability is to provide customer satisfaction and through this to achieve long term market share. Table 1.1 summarises New and Sweeney's views about the differences between the two elements of delivery performance.

	Product Availability	**Delivery Reliability**
Function	Market share	Customer satisfaction
Means	Lead time offered	Accuracy
Determined by	Stock and capacity	Quotes on order intake
Knowledge of	Market forecasts	Capacities, work content, lead times
Adjusted by	Extra capacity	Priorities re-allocation

Table 1.1: Product availability and delivery reliability (after New & Sweeney, 1984).

Product availability may be determined by the capacity a company has, the existing work load and the level of stockholding. It can be improved by the addition of extra capacity. Delivery reliability is determined by the delivery date quotation which management makes to customers when orders are placed and subsequent management of the delivery process. Delivery reliability can be adjusted through changes in relative priorities and the reallocation of capacity and workload.

It is important to consider delivery performance in the context of the manufacturing environment in which the plant operates, i.e. make-for-stock, assemble-to-order or

make-to-order. The next section examines delivery performance in the context of this environment.

1.2 MAKE-TO-ORDER AND MAKE-FOR-STOCK.

A manufacturing plant has a range of policy options open to it, which means that the plant can, depending on its circumstances, choose the length of the customer delivery lead time it quotes to the customer (New, 1977) (Wemmerlov, 1984). The customer delivery lead time is the time between the customer placing an order and receiving it (New & Sweeney, 1984). The customer lead time does not have to equal the total composite manufacturing lead time. The composite lead time for a product is the difference in time between the final due date for the finished product and the date when the first action must be taken in order to get it made (New 1976). The composite lead time may be separated into three elements: material procurement lead time, component manufacturing lead time, and product assembly lead time. The spectrum of options open to the manufacturing plant is presented in Figure 1.1. It also illustrates the relationship between total manufacturing lead times and customer lead times for the various options (Wemmerlov, 1984; Marucheck & McClelland, 1986; New & Myers, 1986).

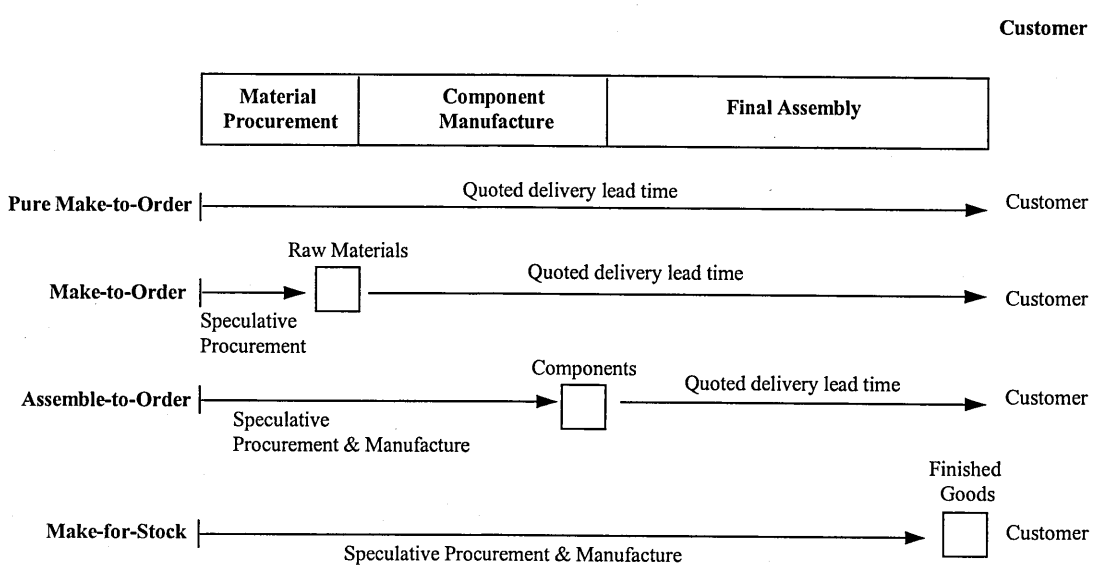

Figure 1.1: Make-to-order, make-for-stock and lead times.

In the pure make-to-order (procure and make-to-order) situation[1], a company offers a quoted delivery lead time to the customer, which is no shorter than the total composite lead time (it can be longer due to capacity reasons - a backlog of orders may be present). In this position the company does not purchase any raw material until a firm customer order is received.

In the more usual, make-to-order situation, the company offers the customer a delivery lead time sufficient to cover the plant manufacturing lead time (component manufacture and final assembly). In this position the assumption is that raw materials are immediately available to be used. The company has to forecast what and how much raw material it should have in stock prior to the arrival of customer orders. Also, in the make to order position a company has a raw material stock point in addition to work-in-process.

In the assemble-to-order position, components, and raw materials, are held in stock and so the customer delivery lead time can be shorter since it is only made up of the assembly lead time. The company will now have to speculate about the quantity of raw materials to purchase and also the amount of raw materials to convert into components. The company has to forecast what and how much of each type of component it needs in order to be able to meet customer orders when they arrive.

Finally, we come to the other end of the spectrum, the make-for-stock position. In this situation the customer delivery lead time is zero; there is of course the despatch time but for all practical purposes the customer does not have to wait for the product to be manufactured, it is available to be taken off the shelf. In the make-for-stock situation the company has to speculate about what products to manufacture, in order to meet customer requirements off the shelf.

[1] Sometimes called Engineer-to-order (Marucheck & McClelland, 1986).

A company can sometimes decide where it positions itself on the spectrum depending on market conditions (Wemmerlov, 1984). It may be able to make-for-stock, but it may decide that it does not want to hold all its product range in finished goods inventory. The company may prefer to keep inventory levels low, by simply assembling to order or making to customer order. Obviously, the market the plant operates in, has some influence on what the plant can do - the market will determine what lead times are acceptable and consequently what position the plant can realistically adopt.

For the sake of simplicity we can separate the spectrum into just two parts; firstly, where the company supplies finished product off the shelf i.e. make-for-stock, or secondly, where it supplies the product on a quoted lead time i.e. make-to-order/assemble-to-order. Constable & New (1976) state that for a manufacturing company, the production problem is one of balancing three principal variables (for a given price structure). These three variables are:

(1) Capacity (output rate)
(2) Finished stock levels (inventory investment)
(3) Customer delivery lead times

In the case of the make-for-stock company, it pre-selects variable (3) as "off the shelf" (or zero) and so this reduces the problem to one of balancing production plans against demand patterns. This is achieved through the management of anticipation inventories. However, in the case of the make-to-order company, variable (2) is set at zero and so it must balance capacity against customer delivery times. This is achieved through the use of backlogs/capacity manipulation and/or adjusting the quoted customer delivery lead time. In this situation ensuring good delivery reliability is important (Handfield & Pannesi, 1992).

New (1976) provides a comparison of the main features of make-to-order and make-for-stock (as can be seen in Table 1.2). The table indicates that differences exist between the two situations.

Characteristics	**Make-to-order**	**Make-for-stock**
Product characteristics	1. Customer specified 2. Large range 3. Expensive	1. Producer specified 2. Small range 3. Inexpensive
Production facilities	General purpose	Often special purpose
Key performance variables	1. Delivery reliability 2. Delivery lead times 3. Unit cost	1. Unit cost 2. Service level (product availability ex-stock)
Main operating problems	1. Progress control 2. Order management	1. Planning of production 2. Forecasting 3. Response to change

Table 1.2: Comparison of the make-to-order and make-for-stock production systems.

Table 1.2 points to the fact that for the plant in the make-to-order situation delivery reliability is an important performance variable. New indicates, that in order to achieve good delivery performance, the company needs to continuously progress control and constantly re-plan - if necessary. Handfield and Pannesi (1992) also state that delivery reliability is a critical variable in the make-to-order situation.

1.3 DELIVERY RELIABILITY

The decision was made to study only one aspect of delivery performance, delivery reliability, rather than both elements. The factors affecting delivery reliability are considered to be different to those affecting product availability (Handfield & Pannesi, 1992), suggesting the need to separate them for analysis purpose. Product

availability, unlike delivery reliability, has received a lot of attention in the literature. This is due perhaps, to increased interest in lead times and lead time reduction, which has come in the wake of the growth in the just-in-time literature. Also to ensure that the research project was manageable and achievable, the decision was taken to focus the research on only one element of delivery performance - delivery reliability.

There are 3 main reasons why delivery reliability is worth researching:

1. It is an area that has received far too little attention from researchers.
2. Delivery reliability is considered to be an important factor that customers consider when selecting suppliers.
3. Finally, delivery reliability is seen by many operations management academics as an important element of manufacturing strategy.

1.3.1 The Importance of Delivery Reliability

A number of studies have, over the years, highlighted the importance of delivery reliability amidst a range of factors that manufacturing companies consider when making decisions about selecting suppliers. A study of the electronics industry found that delivery reliability was the most important criterion for the selection of suppliers (Nicholson, 1989). It was also a major influence in the decision to change suppliers. A study, carried out by Jenkins & Burke (1971), into the main reasons for changing suppliers, identified that obtaining improved delivery reliability was second in importance to obtaining lower price. A study, by Cunningham & Roberts (1974), of the valve and pump manufacturing industry evaluated the service provided by suppliers of steel castings. Cunningham & Roberts found that delivery reliability was the primary element influencing the choice of casting and forging supplier. Evans (1982) in his examination of the various decision criteria used in supplier selection by industrial buyers found that delivery reliability was the most important criterion, just ahead of price.

A more recent study carried out by the UK National Economic Development Council (Christopher, 1992) looked at the experience of companies selected by the automotive manufacturer Nissan as their preferred suppliers to supply their car plant at Sunderland. The companies were asked what they believed to be the key criteria in getting and keeping the Nissan business; Table 1.3 summarises their answers. Table 1.3 indicates the importance of delivery performance, just below quality and considerably ahead of price.

	Reason Given	**% of Responses**
1	Quality	94%
2	Reliability of delivery	92%
3	Commitment to continuous improvement	89%
4	Technical expertise	86%
5	Flexibility / responsiveness	78%
6	Customer orientation	76%
7	Price	71%
8	Good marketing / publicity	38%

Table 1.3: Reasons given for getting and keeping the Nissan business.

Liukko et al (1997) carried out a study of the manufacturers choices of subcontractors in the Finnish metal industry. They found that the manufacturers choices of subcontractors was influenced by their delivery reliability, while offering ISO 9000 quality standard was not highly rated. While, Verman and Pullman (1998) found that although managers said that quality was the most important criteria they selected suppliers on, in reality they actually chose suppliers based largely on delivery reliability.

These studies point to the obvious reason why a company should pursue good delivery performance - customer orders. As the research indicates, good delivery performance not only attracts new customers, it also helps to retain existing ones.

Another reason for business to focus on delivery is to achieve cost savings; poor delivery performance can actually cost money. The most likely direct cost that may impact a manufacturing company is a penalty clause for late delivery invoked by the customer - this however, may not always be the case since not all customers adopt a penalty clause policy.

Nicholson (1989), suggests that there are ten ways to lose money from late delivery; Table 1.4 summarises his view. A number of the losses listed in Table 1.4 can be very significant even though they may not be readily apparent. The losses often become apparent only in the medium to long term, rather than in the short term. It is likely that the losses arising from poor delivery performance are sometimes disguised by other causes or treated as acceptable factors in operating a business.

No.	**Ways to Lose Money**
1	Uneconomic working (smaller batches, special set-up, extra documentation)
2	Extra labour content (shifting labour resources, overtime)
3	Uneconomic purchasing (panic buying to supply a rush job)
4	Inflation losses (in a long delay, costs rise while prices may stay fixed)
5	Penalty clause / damage claim
6	Increased transport charges (e.g. air freight instead of surface transport)
7	Cancellation of orders, loss of repeat business
8	Disruption of other orders' progress
9	Unfavourable currency fluctuations
10	Wasted management time

Table 1.4: Ten ways to lose money from late deliveries (based on Nicholson, 1989).

The last item in Table 1.4, wasted management time, is an area where Nicholson feels costs can be high, but difficult to determine. The cost incurred in trying to deal with a frustrated customer and appealing to the operational staff to achieve miracles are probably high, but very seldom quantified and costed.

1.3.2 UK Delivery Performance

Given the relative importance of delivery reliability, we may ask what has been the level of delivery reliability achieved by UK manufacturing plants in the past?

Delivery Reliability	BIM 1975 Percentage of Plants	BIM 1985 Percentage of Plants
0%	3	2
1 - 25%	10	6
26 - 50%	12	15
51 - 75%	23	31
76 - 100%	51	46
Total	100	100
	(n=153)	(n=224)

Table 1.5: Delivery reliability performance against a quoted due date (New & Szwejczewski, 1995).

Table 1.5 shows the reported delivery reliability performance of plants that completed the 1975 and 1985 BIM survey. The table shows that the delivery reliability performance of the plants over the period declined slightly. In 1975 around 51% of the plants achieved a delivery performance of more than 75% on time, this figure fell slightly to stand at 46% in 1985. So what has happened since 1985?

Delivery Reliability	Percentage of Plants
0 -75%	14
76 - 89%	19
90 - 99%	60
100%	7
Total	100%
	(n=194)

Table 1.6: Delivery reliability performance against a quoted due date - 1993 (New & Szwejczewski, 1995).

Table 1.6 presents the delivery reliability for UK manufacturing plants in 1993 (New & Szwejczewski, 1995). Table 1.6 indicates that around 14% of the plants achieved a delivery performance level of less than 76%. However, around 86% of the plants achieved a performance of more than 75%, and around 67% of the plants achieved 90% or above. Comparing the level of performance in 1985 and 1993 indicates that there has been a dramatic improvement in UK delivery reliability performance. The proportion of plants that achieved a delivery reliability level of less than 76% had fallen from 54% in 1985 to 14% in 1993. However, world class delivery reliability performance of 100%, was only achieved by 7% of the plants. The interesting issue that could be researched further is the breakdown of the plants in the 90-99% range, is it skewed towards 99% or more towards the lower end?

The survey mentioned in the previous section pointed to the importance of delivery reliability to manufacturing companies when they selected suppliers. Let us now examine the extent to which the manufacturing strategy literature considers delivery reliability to be an important strategic variable.

1.3.3 Manufacturing Strategy and Delivery Reliability

As manufacturing strategy has risen in importance since the 1970s, so too has the position of delivery reliability as a key strategic variable. Manufacturing strategy is about the effective use of manufacturing strengths as a competitive weapon for the achievement of business and corporate goals (Swamidass and Newell, 1987). Platts and Gregory (1990) define manufacturing strategy *as the extended pattern of decisions and actions, both structural and infrastructure, which determine the capabilities of a manufacturing system and specify how it will operate in order to meet a set of manufacturing objectives which are consistent with the overall business objectives* .

In the manufacturing strategy literature, delivery reliability has developed from being a minor factor (grouped along with others) to a major strategic variable (Figure 1.2 illustrates the development).

Skinner (1969) stated that strategy places demands on manufacturing in terms of the following four broad competitive priorities: productivity, service, quality and return on investment. In Skinner's work, delivery reliability was placed under the service heading. His approach indicated that delivery reliability is one of a number of factors that helps a company compete.

Hayes & Schmenner (1978), Wheelwright (1978), and Hayes & Wheelwright (1984) developed Skinner's approach further and suggested various competitive priorities that a manufacturing organisation could compete on. However, in each case, delivery reliability was not treated as a separate competitive priority, instead it was placed under the dependability dimension.

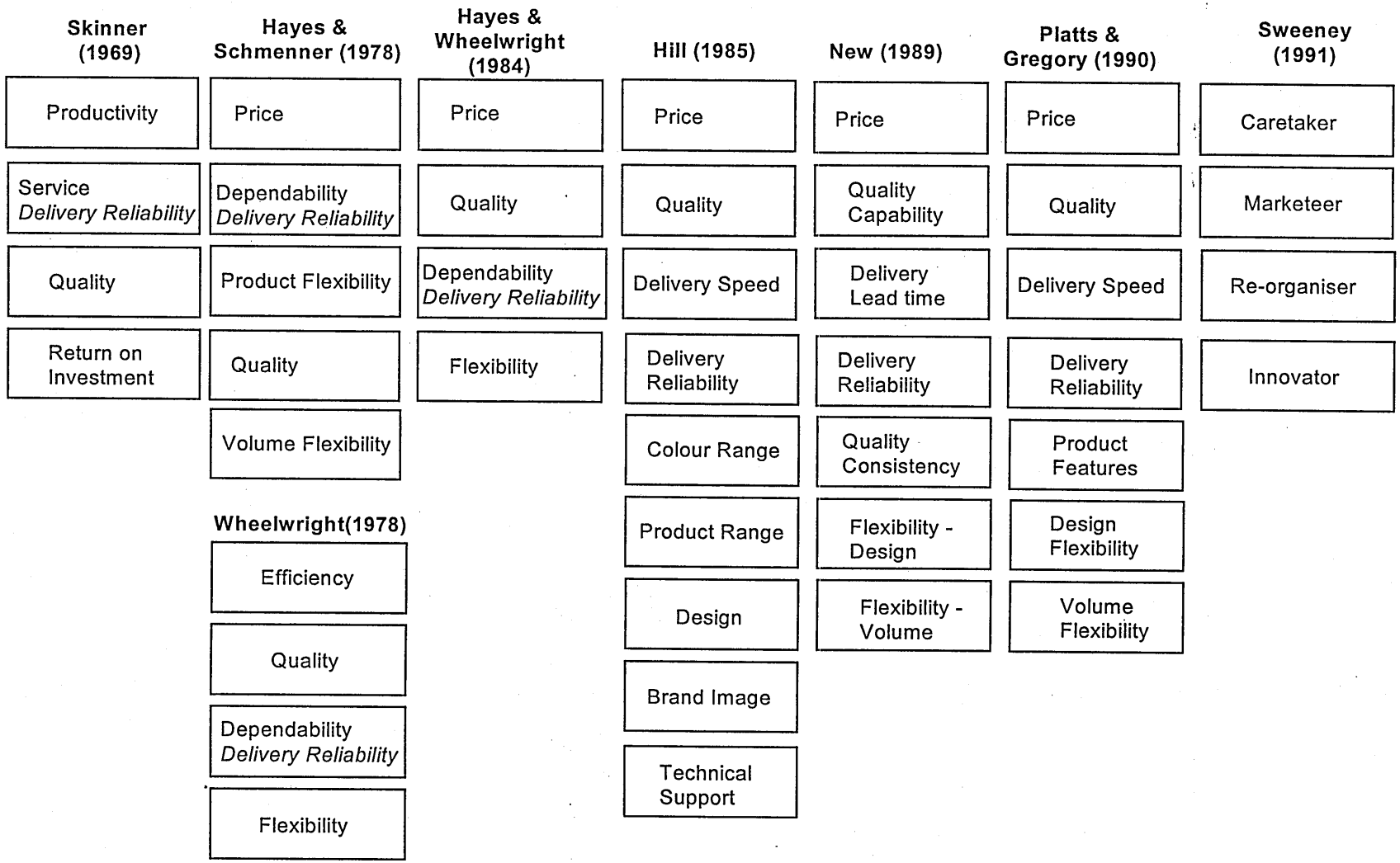

Figure 1.2: Delivery reliability and its development in the manufacturing strategy literature.

Hill (1985; 1993) recommended a slightly different set of criteria[2] (in terms of how the company wins orders): price, qulaity, delivery speed, delivery reliability, colour range, product range, design, brand image and technical support. Unlike some of the other writers on manufacturing strategy, Hill treated delivery reliability as a key competitive priority in its own right, and not subsumed under a variable like dependability.

New (1989) also redefined the criteria, he called them competitive edge, they were the elements that a company competed on[3] in the marketplace. The criteria are: delivery lead time, delivery reliability, quality capability, quality consistency, design flexibility, volume flexibility and price. New, considered delivery reliability to be a factor that manufacturing companies can compete on - a key competitive factor. While, Platts & Gregory (1990) proposed seven competitive criteria on which a company's products compete within the market. One of these criteria is delivery reliability.

However, two writers have changed the position of delivery reliability. Slack (1991) proposes five areas where manufacturing can give an advantage over the competition in its' market place. One of these advantages, the dependability advantage contains delivery reliability. While, Sweeney (1991) contends that the manufacturing strategies followed by companies fall into four generic types: caretaker, marketeer, reorganiser and innovator. Delivery reliability is one of the criteria that make up each generic type.

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[2] Hill recommends that a company should determine which criteria are order winners and which are qualifiers. The qualifiers are those criteria that get a company into and maintain it in a market but they do not win orders. Qualifiers have order losing rather than order winning characteristics - if you do not have them you will lose the order. The order winners, on the other hand, are those criteria that have to be provided in order to win orders from competitors.

[3] The criteria could take one of two forms; either market hygiene factor or competitive edge criterion. The hygiene factors allow you to take part in the game; to be in particular markets you must have them, but they do not help you win orders - to do that you need to be strong on the competitive edge criteria.

Over the years since Skinner first outlined his approach to manufacturing strategy the position of delivery reliability has increased in prominence as one of the competitive variables. Delivery reliability has moved from being part of the dependability criterion to becoming an important criterion in its own right as can be seen in the work of writers such as Hill (1985), New (1989) and Platts & Gregory (1990). Delivery reliability has become recognised in its own right, as a competitive criterion, an important factor that helps a company win orders in the market place. Given the importance of delivery reliability, we need to improve our understanding of the factors that have a major impact on it - what produces good delivery reliability performance?

1.4 AN OUTLINE OF THE RESEARCH.

1.4.1 The Research Focus

The review of the literature concerned with delivery reliability led to six research questions, relating the impact of a number of variables on plant delivery reliability. These six research questions led to the development of two hypotheses[4] and four propositions[5]. Table 1.7 outlines the hypotheses and propositions.

The first hypothesis concerned the impact of customisation on delivery reliability. This hypothesis was based on the supposition that plants that manufactured customised products achieved a lower level of delivery reliability performance than plants that manufactured only standard products.

The second hypothesis was related to the impact of part complexity on delivery reliability. It was based on the supposition that plants that manufactured complex

[4] A hypothesis is a conjectural statement about the value of some variable or the relationship between variables that will be tested and ultimately accepted or rejected on the basis of statistical analysis of data (Alreck & Settle, 1985).

[5] A proposition is a theoretical statement that specifies the connection between two or more variables, indicating how variation in one concept is accounted for by variation in another (Neuman 1997).

products had poorer delivery reliability than plants that supplied less complex products.

The research also examined four propositions. The first proposition examined the impact on delivery performance of the delivery quotation being provided by the production planning department or another department. One of the most important

HYPOTHESIS	
H1 Customisation	Plants that manufacture a low proportion of their output as customised products are likely to have a higher level of delivery reliability than those plants that manufacture a higher proportion of their output as customised products.
H2 Complexity	Plants that manufacture relatively complex products are likely to have lower levels of delivery reliability than plants that manufacture relatively simple products.
PROPOSITION	
P1 Planning Authority	In plants where the production planning department determines the delivery quotation, the level of delivery reliability will be high.
P2 Customer Expectations	In plants where the customers have expectations of high levels of delivery reliability, the level of delivery reliability will be high.
P3 Management Focus	In plants where the management team is predominantly focused on delivery reliability, the level of delivery reliability will be high.
P4 Performance Focus	In plants where the performance measurement system has delivery reliability as a key area of focus, levels of delivery reliability will be high.

Table 1.7: Research hypotheses and propositions.

activities involved in ensuring good delivery performance is the process of delivery date quotation. If the delivery date is unrealistic then this means the order will not be produced and supplied by the quoted delivery date. The department with most of the information that will help them develop a realistic delivery date quotation is usually the production planning department. However, the production planning department does not always supply the delivery date quotation. The first proposition suggests that

plants where the production planning department determines the delivery quotation, the level of delivery performance will be high.

The second proposition was linked to the issue of whether customers with expectations of high levels of delivery performance resulted in plants having high levels of delivery performance. Customers can have a strong influence on manufacturing plants by demanding when the order is to be delivered rather than when the plant feels it can deliver the order. So, the question is what is the actual influence of the customer on the plant delivery performance, do demanding customers drive plants to provide high levels of delivery performance?

The third and fourth propositions were linked to the focus of the management team, the performance measurement system and the impact this had on plant delivery performance. The research examined the impact of the focus of the management team on delivery performance. Writers have pointed to the need for the whole plant management team to be focused on delivery performance. The research examined if there was any difference, in the degree of focus, between those plants with high delivery reliability and those with low delivery reliability. Allied to the issue of the focus of the management team was the focus of the performance measurement system used in the factory. It has been stated that the performance measures used may influence the actions of employees. The research examined whether there was any difference in the performance measurement system focus between those plants where delivery reliability was high and those where it was low.

1.4.2 Methodology

Delivery reliability is an area where, as Handfield and Pannesi (1992) point out, little research has been carried out, compared to other strategic variables such as quality. Due to the small base of empirical studies and the fact that some of the variables and

their relationship with delivery reliability had not been extensively examined, this research was necessarily exploratory in nature.

The research started (stage 1) with a literature review into the factors that impact delivery reliability. The literature review led to the development of a series of research questions (stage 2). These gave rise to two hypotheses and four propositions. Various approaches (such as the survey approach) were considered for the research project.

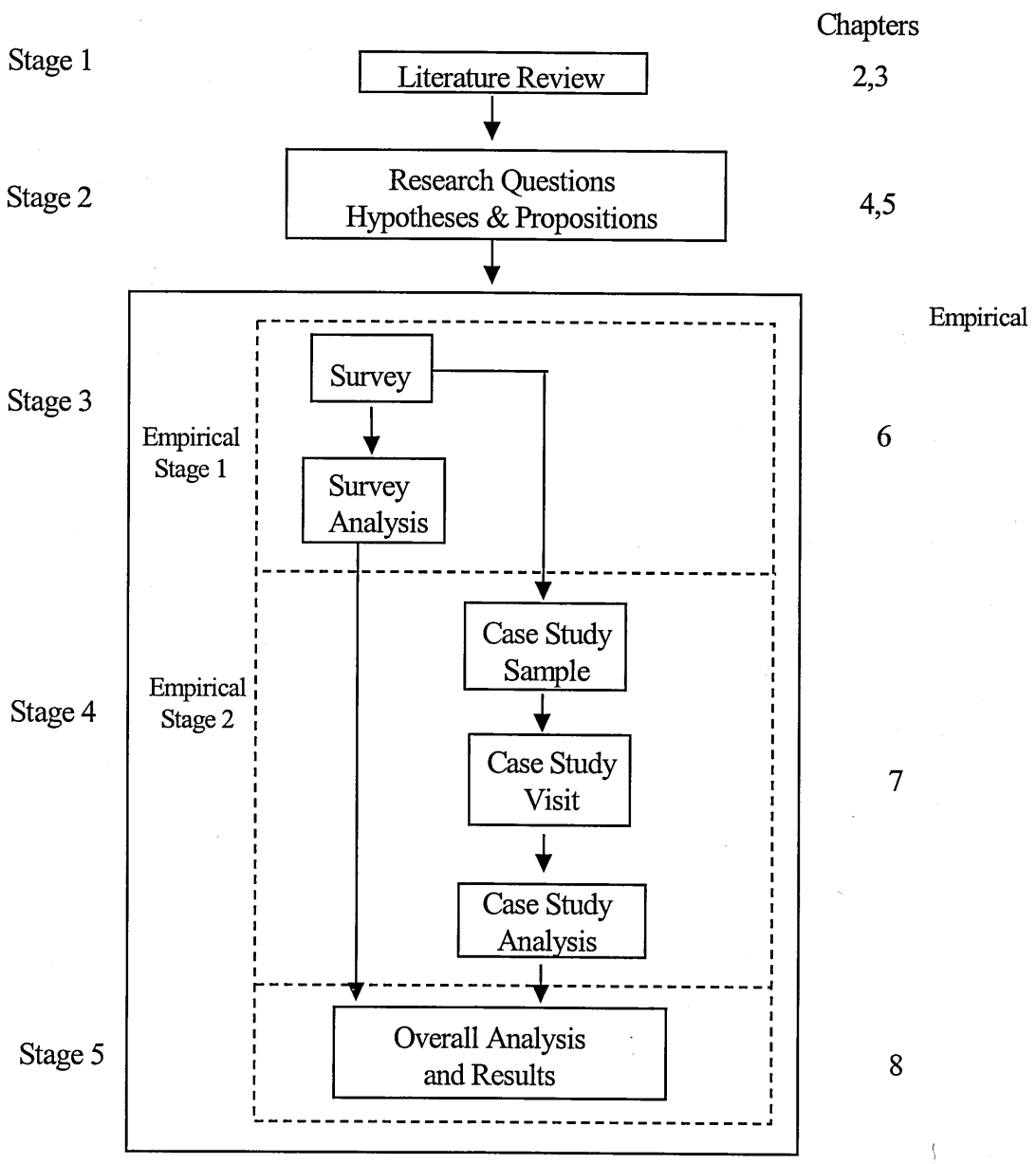

Figure 1.3: The key stages of the research project.

However, the two hypotheses and the four propositions that were developed could not be investigated successfully using just one research approach. For this reason, it was decided to use more than one approach (as shown in Figure 1.3).

Firstly, a survey of UK manufacturing plants was used (stage 3). This was followed by the use of a series of case studies (stage 4). During stage 3 (empirical stage 1) , a large survey of UK manufacturing plants was analysed to determine if the two hypotheses, in Table 1.7, were correct. Stage 4 (or empirical stage 2) involved using the plants that responded to form a sample from which the case studies could be selected. The case study phase of the research included a pilot study. The main phase of the research involved visits to four pairs of plants, the matched pairs were taken from the group of plants that completed the survey questionnaire. Each pair consisted of one plant with poor delivery performance and one with high delivery performance. Since the survey questionnaire collected data about plant delivery performance it was possible to select plants with good and poor performance (and create the matched pairs). The use of a pool of plants provided the researcher with the ability to control for possible key intervening variables and therefore to select pairs of similar plants - similar, except for the level of delivery performance. The case study stage of the research was used to investigate if the four propositions (presented in Table 1.7) could be accepted.

The final stage of the research involved bringing the results of the survey and case study research together and carrying out an overall analysis.

1.5 THE INTENDED CONTRIBUTION OF THE RESEARCH

Over the years a growing body of theory concerning manufacturing strategy has developed in the operations management literature. However, this theory base is skewed, Handfield and Pannesi (1992) point out that only two of the strategy variables (price and quality) have been researched to such an extent that managers now know which resources in a firm improve price or quality competitiveness. While other

competitive variables, such as delivery reliability, have been identified as important, they have not been as extensively researched. The intention of this research is to add to the operations management knowledge base about delivery reliability.

Previous research looking at delivery performance has tended to focus on the impact of the production planning system on delivery performance (Handfield & Pannesi, 1992). It is intended that this research will help to develop an understanding of what the possible impacts of other less researched factors, such as customers and management, have on delivery reliability. In addition, the intention is to provide Operations Management practitioners with some information about which variables inhibit delivery reliability.

1.6 THE STRUCTURE OF THE THESIS

The thesis is divided into nine chapters. Chapters' Two and Three give a review of the literature relating to delivery reliability. Chapter Two addresses the first part of the literature review, examining areas such as delivery date quotation. While Chapter Three, takes the literature review further and examines those areas that are seldom discussed in the delivery performance literature.

In Chapter Four, a conceptual model of the delivery management process was presented. The chapter also proposes a number of research questions, and then goes on to develop the hypotheses and propositions. The various methodologies that could be used to test the hypotheses and propositions are presented and discussed. The final approach, which was a mix of survey and case study, is then outlined.

A detailed explanation of the research design (the case study and the survey) is presented in Chapter Five. The chapter discusses why the postal survey approach was used, and covers the issue of questionnaire design. Other related subjects such as the piloting of the questionnaire, the sample used and the types of data analysis undertaken

are also covered. The chapter explains in detail the case study approach adopted, how the paired sample was arrived at, the areas investigated in each plant, the individuals interviewed, and the analysis approach used.

Chapter Six, presents the results of the analysis of the data collected using the postal questionnaire. The full results of the analysis are presented, and then compared with the two research hypotheses outlined in chapter Four. From this comparison, conclusions are drawn and presented. Chapter Seven, covers the case studies and presents a full cross case comparison of the eight cases. The results from the case studies are compared with the four propositions (outlined in Chapter Four) and conclusions are drawn.

The survey and case study results are brought together in Chapter Eight. The results from the survey and the case studies are discussed in the light of the original model presented in Chapter Four.

Chapter Nine, provides a concluding summary of the research. It reviews the research results, the conclusions that can be drawn and the areas to which they are applicable. The limitations of the research are acknowledged, suggestions for rectifying these are made, and recommendations for further research are given.

1.7 SUMMARY

Delivery reliability is an important element of manufacturing strategy. Good delivery reliability is important because it has a positive impact on customer satisfaction. The research described in this thesis tries to determine the impact of several variables on plant delivery performance. In particular the research examines the impact of part complexity, product customisation, management and performance measurement focus on a plant's delivery reliability performance.

The research methodology consisted of two elements - a survey and case study. The nine chapters in this thesis cover all the elements of the research including the literature review, research questions, hypotheses, how the research approach was developed, the methodology, the results and the research conclusions. The conclusion to this thesis includes a section on the degree to which the results can be generalised and ideas for further research.

CHAPTER 2

LITERATURE - OPERATIONAL FACTORS

2.0 INTRODUCTION

This chapter and the next one will cover the operations management literature that related to delivery reliability. A review of the literature has identified a large number of factors that have an impact on delivery reliability. These factors have been classified into two groups (as shown in Figure 2.1).

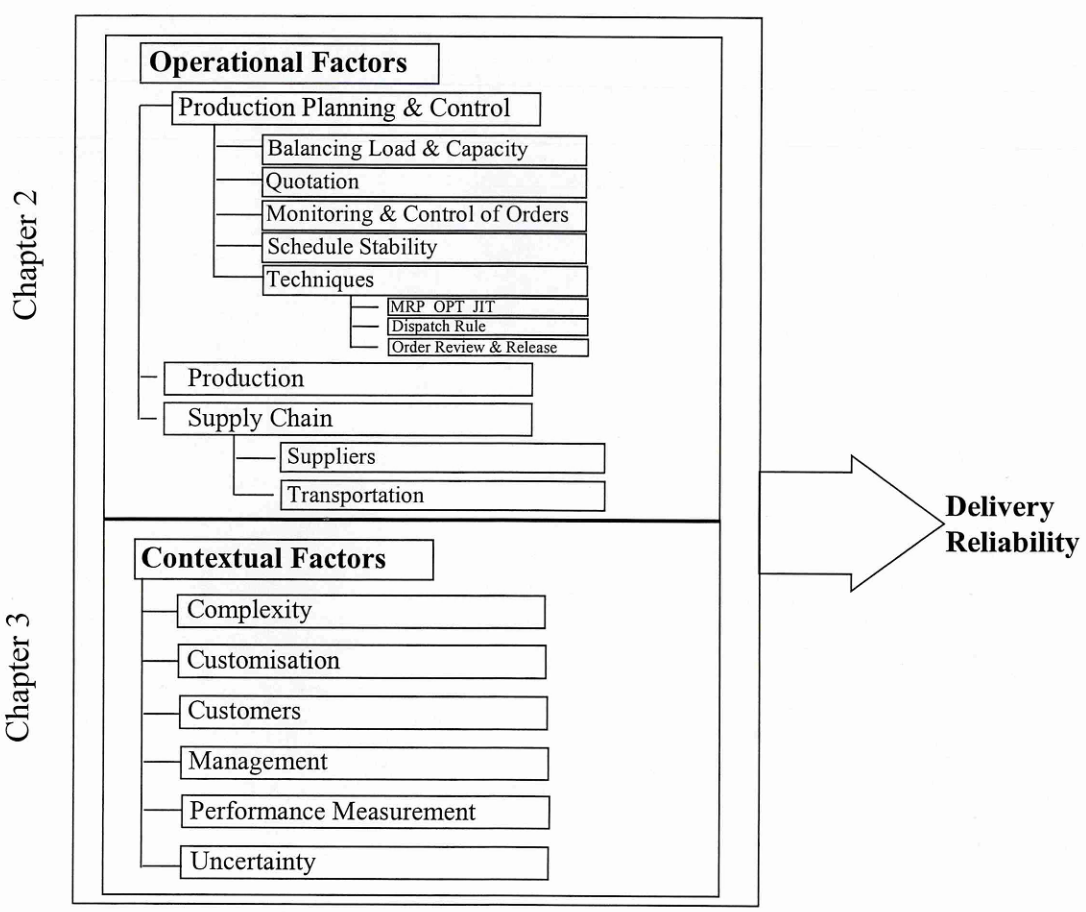

Figure 2.1: The operational and contextual factors that impact delivery reliability.

The two groups are as follows:

- Operational Factors: These cover those factors relating to the operation of the manufacturing plant. One of the major operational factors is production planning and control.
- Contextual Factors: These are those factors related to the context that the manufacturing plant operates, and which are considered to have an impact on delivery reliability.

Chapter Three will cover the contextual factors, whereas this chapter will cover the three main topic groups: production planning and control (section 2.1), production (section 2.2), and the supply chain (section 2.3). For the topic of production planning and control a number of specific areas will be examined in particular balancing load and capacity, the quotation of the delivery date and the monitoring and control of orders. Let us start by examining the impact of production planning and control.

2.1 PRODUCTION PLANNING AND CONTROL

The production planning and control system deals with all the activities from the acquisition of the raw materials to the delivery of completed products (Vollmann et al, 1988). Several writers (Corke, 1977; Paulden, 1977; Leonard, 1978; Nicholson, 1979; Hill, 1989; Handfield & Pannesi, 1992) contend that the production planning and control system has an important role to play in ensuring good delivery reliability. The system can:

- Help to provide realistic delivery dates to be quoted by taking account of existing commitments.
- It can establish correct priorities (what is needed and when) and help ensure that capacity is available to meet these priorities.
- Also control the flow of work to meet the delivery dates quoted and to provide information about possible delays before they arise or become serious.

Nicholson (1979) in his case study research on UK and Canadian manufacturing found that the companies he examined were all of the opinion that production control was a key activity to ensure company success, in particular in the area of delivery reliability.

Figure 2.1 shows the elements of production planning and control that the literature suggests may impact delivery reliability. Let us now examine each of these factors in turn, starting with the balancing of load and capacity.

2.1.1 Balancing Load and Capacity

Over the years many writers have commented that key to production planning and control is ensuring that a level of work is not fed into a factory in excess of its capacity (Plossl & Wight, 1973; New 1977; Mather & Plossl, 1978; Corke, 1978; Fry, 1990). If this happens a manufacturing plant will lose control of its output, an eventual consequence of which may be a decline in delivery reliability. This is because the flow of work through a factory is limited by its capacity. If the level of capacity available in the factory is inadequate to handle the level of work (the load) then the level of work-in-process in the plant will rise, queues will grow and manufacturing lead times will get longer and more erratic. When load exceeds capacity the plant will have difficulty in meeting delivery due dates.

Kanet (1982) points out the important role that the utilisation rate (the ratio of average input to average capacity output rate) has on the level of work-in-process and manufacturing lead times[1]. He contends that an increase in the utilisation (which must be less than 1) can have a dramatic effect on manufacturing lead times and work in process. At low levels of utilisation the average lead time is short but as the utilisation figure approaches 1 the average lead time begins to rise dramatically. Figure 2.2

[1] Kanet's approach is based on Little's Law (1961) which states that the level of work-in-process inventory in the plant and manufacturing lead times are related to each other. As work in process increases so manufacturing lead times get longer.

illustrates the dramatic impact of increasing utilisation can have on lead times. Kanet states that this relationship is relevant for the whole of a manufacturing plant, and not just one work centre.

South (1985) supports the model presented by Kanet and presents some simulation evidence to show the impact on manufacturing lead times of an increase in utilisation. Harrison, Holloway and Patell (1990) comment that both the queuing theory and practical experience points to the fact that the actual manufacturing lead time tends to be a statistical distribution rather than a single number. They comment that the mean manufacturing lead time (and its variance) increase as the factory production rate increases (given constant capacity), and the mean manufacturing lead time adopts the characteristic convex shape shown in Figure 2.2.

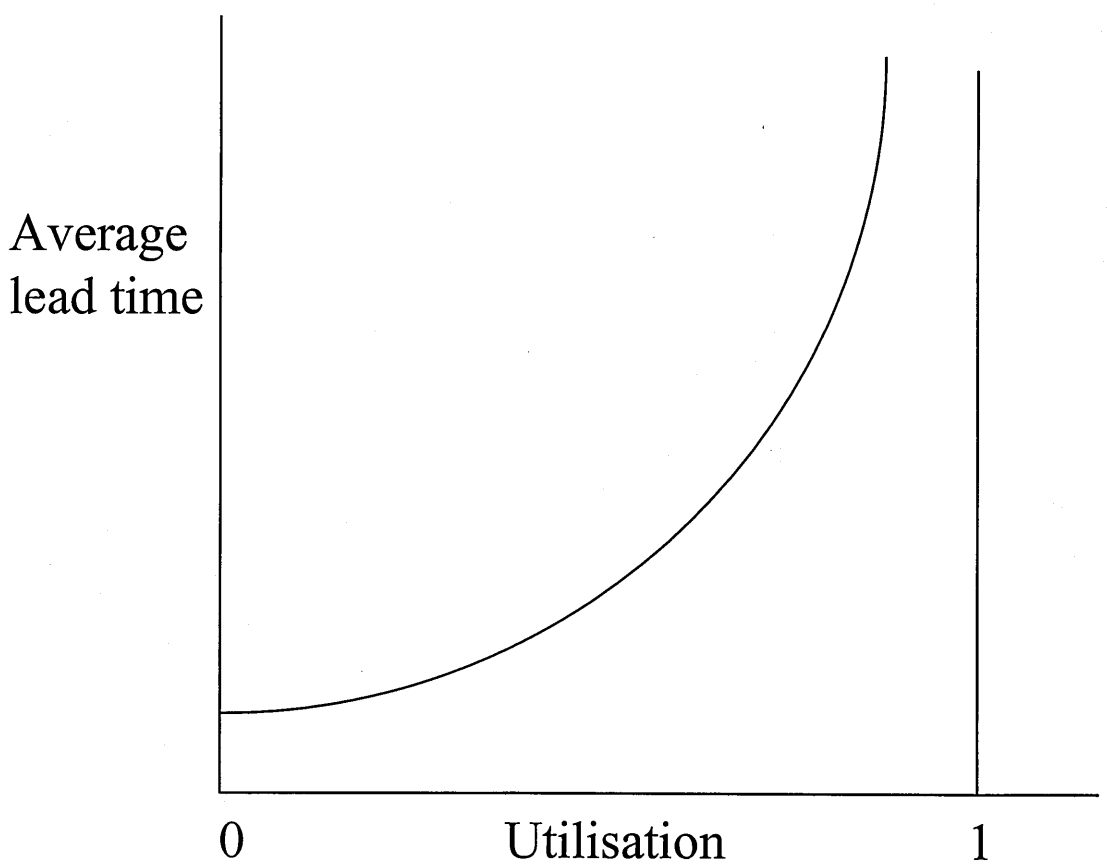

Figure 2.2: The effect of utilisation on average lead time. (Based on Kanet, 1982).

While Kanet describes the impact of increased utilisation on manufacturing lead times he does not go on to consider the impact on delivery reliability. The work of Constable and New (1976) describes the likely impact on delivery reliability of overloading the factory as shown in Figure 2.3.

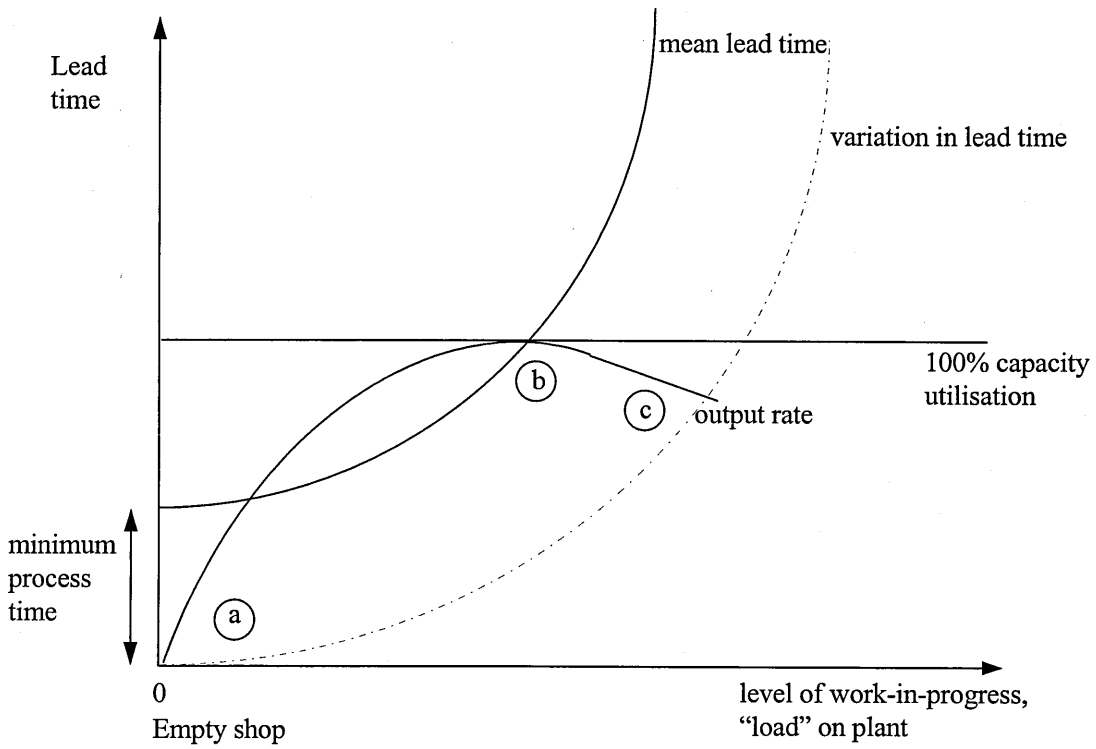

Figure 2.3: A conceptual representation of the relationship between lead time, work-in-process and capacity (Based on Constable & New, 1976).

In the empty factory the manufacturing lead time can be very close to the actual minimum technical process time for an order. When the factory starts work on the first order work-in-process is low and so the manufacturing lead time is short (at point a). As the number of orders entering the factory grows so queues begin to form at work centres and work-in-process inventory increases. The increase in orders increases the size of the queues and the manufacturing lead times become longer. Moreover, the increase in manufacturing lead times may also lead to an increase in the

variation in these lead times, manufacturing lead times are no longer stable, they start to vary. However, although the manufacturing lead time increases the level of output of the factory also increases, because of the higher utilisation of the factory capacity. Output, manufacturing lead times and manufacturing lead time variability all increase as order input increases, until the capacity ceiling is reached (point b). Once the rate of order input begins to exceed the capacity ceiling then the actual level of output may begin to decline (point c). As the work-in-process rises, the physical congestion in the factory will prevent efficient materials movement and so output will drop. Also 'hot' orders (orders being chased to meet delivery promises) become more numerous, causing disruption to the schedule and may involve extra set-up time leading to lower total output. The variation in the manufacturing lead times also increases dramatically making it very difficult to predict the completion time for a particular customer order. The variability in the manufacturing lead times means that some customer quoted delivery dates will not be met and so orders will be delivered late (delivery reliability will decline). The variability in manufacturing lead times also makes it more difficult to provide accurate delivery date quotations for new orders.

The solution to an overloaded system is, according to Constable & New, to control the total volume of work in the factory; to do this requires a reduction in the level of input for a period of time. Once the work-in-process (WIP) level has been reduced, the level of input can be restored to match the factory's capacity.

The Constable and New model was based predominantly on experience and anecdotal evidence. However, the research carried out by Shimoyashiro, Isoda and Awane (1984) tends to confirm the Constable & New model. Shimoyashiro et al investigated the relationship between production output and manufacturing lead time using simulation. They found that when WIP was small, the production output increased in proportion to the increase in WIP, and the manufacturing lead time also increased in proportion to the change in the level of WIP. Once full capacity had been achieved the production output did not increase as WIP increased. However, although output

did not increase, the manufacturing lead time continued to increase in proportion to the increase in WIP.

Shimoyashiro, Isoda and Awane's simulation results indicate that once full capacity has been reached output stops growing and continues to stay constant as the level of WIP increases. However, Constable and New indicate that this is not the case. They suggest that the level of output falls, once full capacity has been reached, because of the increased congestion on the shopfloor and the increased number of "hot orders" being expedited. Hence the output rate curve turns down in their model (see Figure 2.4).

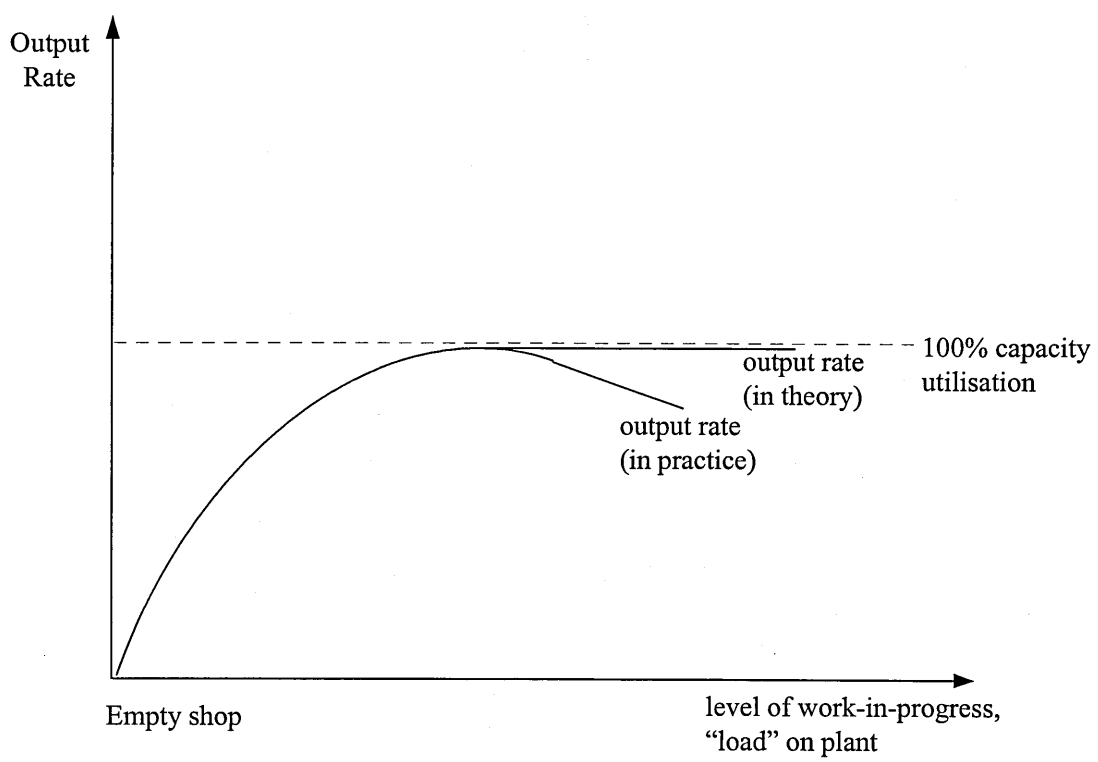

Figure 2.4: Change in output rate.

This section has examined the issue of balancing load and capacity. The literature indicates that as the load placed on the factory rises so output levels increase, WIP increases and manufacturing lead times increase. However, when the load exceeds

capacity then output levels will fall and delivery reliability will also decline. Hence the importance of ensuring that the load and capacity are in balance, in order to ensure good delivery reliability.

Making sure that load and capacity are in balance is just one element of ensuring good delivery reliability. The literature points to the fact that the delivery date quotation activity is also important. The next section examines the area of quotation and its impact on delivery reliability.

2.1.2 Delivery Date Quotation

A manufacturing company operating in a make-to-order environment provides customers, in response to an order enquiry, with a quoted delivery lead time, a delivery date, and usually a price. The quoted delivery lead time may help the company to win the order, but the delivery date also becomes a target that the factory has to achieve. As has already been stated (in Chapter 1) quoting a competitive lead time (good product availability) to a customer may initially win the plant orders, but then failing to deliver the order on time (poor delivery reliability) is likely to lose the plant future business.

Paulden (1977) states that the delivery date quotation stage is very important to ensuring good delivery reliability. In his view the cause of most late deliveries can be traced back to the fact that an unrealistic delivery date was promised. Quoting an unrealistic delivery date sets an almost impossible goal for the manufacturing plant to achieve. Other writers also stress the importance of the quotation. Tatsiopoulos and Kingsman (1983) suggest that poor delivery reliability can be due to wrong commitments made by the company to customers at the delivery date quotation stage, while Hendry and Kingsman (1989) state that it is essential to quote delivery dates which can be achieved with the capacity available in the factory. Paulden (1977), Tatsiopoulos and Kingsman (1983) and Hendry & Kingsman (1989) all point to the

importance of the quotation stage to ensuring good delivery reliability, however, they offer no more than anecdotal evidence to support their assertions. Some evidence is, however, offered by Houseman (1978). His survey of managing directors investigated the reasons for poor delivery reliability found that one of the major reasons given for late delivery was excessive optimism in estimating delivery dates. However this research suffers from the drawback of being based solely on the managing directors' perceptions.

The delivery date can be decided by the plant, but it can also be demanded by the customer as a condition of doing business, or it may be decided as a result of negotiation between the two parties. Young, Kwong, Li and Fok (1992) examined the manufacturing practices of manufacturing companies in two industry sectors (small machine tools and non-fashion textiles) in China, Korea, Japan, Western Europe and the USA (using data from the Global Manufacturing Research study). They examined how the delivery date was determined: by the customer, by the supplier or through negotiation. Table 2.1 presents who determined the delivery date.

	Percentage Responding				
	China	**Japan**	**Korea (S)**	**Europe**	**USA**
Machine Tools					
Mostly by customer	14	33	65	18	24
Negotiation	70	33	19	59	22
Mostly by us	14	33	9	23	42
No response	2	1	7	0	12
Textiles					
Mostly by customer	34	44	45	38	40
Negotiation	52	42	18	42	20
Mostly by us	11	6	12	20	38
No response	3	6	25	0	2

Table 2.1: How is the delivery date determined (based on Young, Kwong, Li and Fok, 1992).

Table 2.1 shows that the Korean manufacturers were more customer-driven in both the industries than the Japanese, Chinese, European or US companies. It is also interesting that a large proportion of the European companies surveyed (in both sectors) determined the delivery date via negotiation. However, their research did not indicate if there was any difference in the delivery reliability of the companies where the customer determined the date, where they negotiated the date, or determined the date themselves. Brown and Vastag (1992) investigated this issue (using data from the Global Manufacturing Research study for Europe). They examined the hypothesis that delivery reliability would be best under circumstances in which the due date is negotiated with the customer. They found that the method of delivery date determination did not have a significant influence on delivery reliability -- the hypothesis could not be accepted.

The provision of the delivery date quotation can come from several departments within the manufacturing company. Table 2.2 presents the results of two surveys (New, 1976; New & Myers, 1986) concerning which department was responsible for the quotation of customer delivery dates.

	% Plants in 1975	% Plants in 1985
Manufacturing Function		
Production/Inventory Control	47	30
Manufacturing Management	8	9
	57	39
Marketing Function		
Marketing/Sales	27	36
Customer Service	7	12
Contract Administration	4	6
	38	54
General Management	4	1
Other	3	6
Total	100% (n=159)	100% n=(230)

Table 2.2: Function responsible for quoting delivery dates (New, 1976; New & Myers, 1986).

In 1975, in 55% of the cases the due date was quoted by the Manufacturing function, either production control or manufacturing management. However, as Table 2.2 indicates, New also found that for 38% of the plants the due dates were quoted by a marketing function (marketing/sales, customer service or contract administration).

In their 1985 survey, New and Myers found that in 39% of the plants the responsibility for quoting due dates rested with production control or manufacturing management, while in 54% of the cases the due date was quoted by the marketing function. Table 2.2 indicates that the situation had changed over the ten years, in a majority of the plants the marketing function was now responsible for quoting the due date. New and Myers make the point that there is a danger of over commitment of capacity, if marketing does not consult manufacturing, before it issues a delivery date to the customer. The manufacturing function, especially production planning, has a better understanding of what capacity is available to produce the customer order and so is less likely to over-commit capacity than the other departments (such as the sales department). However, a limitation of the this study is the authors did not examine if there was any difference in actual delivery reliability depending on which function was responsible for the delivery date quotation.

While the function which has responsibility for the delivery date quotation can have an impact on delivery reliability, so too can the method used to determine the delivery date. A number of writers (New, 1977; Nicholson, 1982; McClelland, 1988; Hatoum & Chang, 1997) contend that in order to arrive at a realistic delivery date it is also important to take account of the load and capacity of the manufacturing operation. The estimation of a realistic delivery date requires information about how long it takes to make the product and also knowledge of the existing load on the plant, the capacity available and any other outstanding commitments. Therefore, to base the delivery date quotation simply on an estimation of how long it takes to make the product,

without looking at the current and future load and the plant capacity, will lead to a quotation of a delivery lead time that is unrealistic.

Nicholson (1982) examined the quotation process of 11 manufacturing companies with poor delivery reliability. He found that the process of quoting due dates was often made using assumed historic manufacturing lead times and often neglecting current and future load. This research gives some tentative evidence to indicate that the approach used to determine the delivery date may impact delivery reliability.

While, McClelland (1988) carried out simulation research and found that delivery reliability improved when the method used to arrive at the delivery date took into account the load and capacity. However, her research suffers from the drawback of being simulation based.

It can been seen from the literature presented in this section that the quotation stage is important in ensuring good delivery reliability. A number of writers indicate that when determining the delivery date it is important to take account of the load and capacity of the manufacturing operation. There is some research evidence to indicate that the approach used to determine the delivery date can impact delivery reliability.

The literature indicates that different functions may be responsible for the delivery date quotation. However, there is no evidence to indicate that there is a difference in delivery reliability depending on which department is responsible for the quotation. In addition, previous survey research shows that there is no significant difference in the delivery reliability of plants where the delivery date was negotiated and where either the customer or the plant mainly determined the delivery date.

2.1.3 Monitoring and Control of Orders

The monitoring of delivery reliability has a role to play in ensuring high levels of delivery reliability. Several writers stress the importance of monitoring delivery reliability. Paulden (1977) considers that it is important to measure the plant's delivery reliability, monitoring the production plan and also the progress of orders through the factory. For him monitoring is an important activity, helping management to identify problems at an early stage, thereby ensuring that a disaster can be avoided or at least its effects minimised. As Paulden points out, corrective action such as using spare capacity cannot be taken unless the monitoring system is in place and being utilised. Nicholson (1982) too, advocates that delivery reliability should be monitored and receive more management attention. The whole management team should be concerned about the level of delivery reliability on a regular basis. Slack (1991) makes the point that it is important to monitor progress closely. For him, a surprisingly common cause of lateness is the fact that internal delivery dates are overlooked. He makes the point that every day internal lateness is not picked up, is a day less to do something about it, for Slack an efficient monitoring is essential. Kumar and Sharman (1992) state that from their experience the companies with poor delivery reliability performance did not measure it at all. The authors contend that actually measuring delivery reliability will result in an improvement in performance.

However, it is important to note that simply monitoring delivery reliability and the internal progress of orders is not the be and end all. Monitoring should be followed by action, otherwise poor delivery reliability will not be corrected and the situation will not improve. Nicholson (1989) points to a survey (looking at late delivery) of the fabrication industry that found that the companies examined all had monitoring systems, but few of them actually used their systems to take action to prevent future delays occurring on current orders or indeed future delays happening on future orders.

New & Sweeney (1984) propose one of the few models of delivery reliability, which has control as an important element. They called their model the Total Delivery Management concept (Figure 2.5); a key element of their model is monitoring and control.

This model has three control loops. Two of the control loops fall within the domain of the company. The principal control loop is the one between quotation of the delivery date on order acceptance and the despatch reliability actually achieved against this (i.e. delivery reliability). New & Sweeney contend that the main problems associated with this control loop are:

- Competitive pressure on lead times (product availability)
- An uncertain success rate on bids for tender

The tools to aid overcoming the problems are:

- Load - capacity balancing techniques for forward planning of commitments
- Selective bidding strategies -- such that low bids may be put in for orders requiring underloaded facilities and very high bids for orders requiring already overloaded facilities.

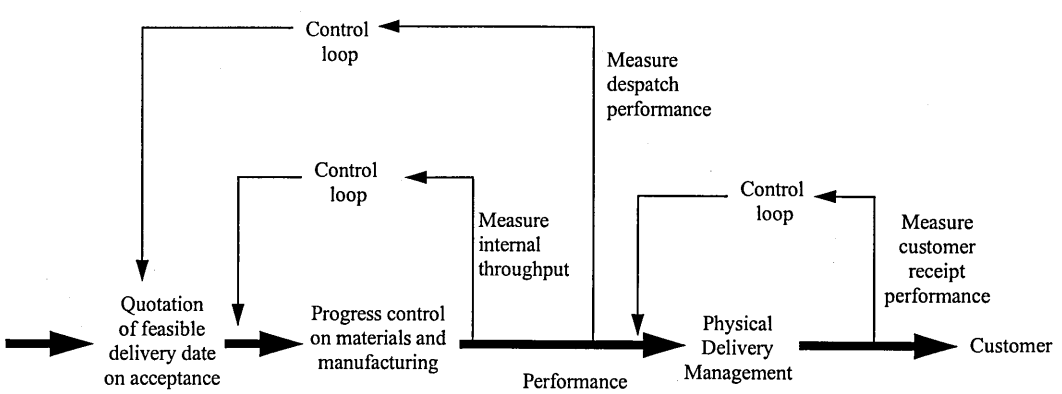

Figure 2.5: The Total Delivery Management Concept.

The second control loop is the inner control loop monitoring the internal throughput performance; that is the actual progress control on materials procurement and manufacturing. They state that the internal control loop is a very useful concept when trying to identify the causes for poor delivery performance, but they note that it is often difficult to measure directly. The problems associated with physical throughput control are primarily:

- Supplier control of bought out items.
- Engineering release control of product specifications, drawings etc.
- And also the normal production control progress function.

The aids available to handle these problems are the standard tools of production planning and control namely:

- Monitoring WIP progress
- Control of relative priorities
- Managing job progress through the shop
- Planning capacities for future commitment
- Monitoring supplier performance

The physical delivery management control loop involves measuring the actual customer receipt performance i.e. did the product/order arrive at the customers premises at its agreed time. The factory may achieve its agreed despatch date but due to transportation delays it may miss the customer delivery date. New & Sweeney indicate that the aids available to management are transportation know-how and use of standard documentation.

While writers such as Paulden (1977) and Kumar and Sharma (1992) point to the importance of monitoring delivery reliability, they offer little evidence to support their views. However there is some research that looks at the impact of monitoring delivery reliability. New (1976) found in his 1975 survey of UK manufacturing industry that there was no significant difference between the delivery reliability of those plants that

monitored their delivery reliability (around 60% did monitor) and those plants that did not monitor their delivery reliability. He stated that it seemed that, even at those plants that did monitor performance, little management action was taken as a result of this poor performance. The conclusion New draws from this is that the function responsible for monitoring (e.g. manufacturing management or production control) did not have the authority or means to improve the situation. Overall, New concluded that the poor delivery reliability of the plants could be due to either:

- the available capacity had been over committed in terms of orders placed upon it, or
- control of the flow of orders was inadequate to ensure that they were finished on schedule

He stated that the inadequate control of the flow of orders to ensure that they were finished on schedule could be seen as a sub-problem of over-committed capacity - i.e. the lower the load on the facilities the better the control. Nevertheless, for New it is certainly possible to improve control through careful monitoring of the actual progress of orders.

New and Myers (1986) followed up on the 1975 New survey. They found that plants which monitored their delivery reliability performed markedly better than those that did not, and this difference was significant. They concluded that there was now considerable evidence to suggest that those plants that monitored their delivery reliability were now significantly outperforming those plants that did not do so.

Nicholson (1982) in his study of 11 companies found that poor delivery reliability was partly caused by poor monitoring of orders. He found that an order tended to be recognised as overdue only when it had already missed its customer delivery date, rather than it being recognised as being "potentially" overdue at an early stage of production. Nicholson makes the point that the lack of control over delivery was rarely noticed by senior management, because their principle monitoring mechanism

was the budget which had no explicit connection with delivery reliability. Consequently they were unaware of just how poor their delivery reliability performance was.

Further evidence indicating the importance of monitoring can be found by examining the results of the research carried out by New and Sweeney (1984). They found from their case study research that the plants with poor delivery reliability were very reactive in their approach to managing delivery. The major stimulus for production management to complete overdue orders was from external feedback, such as customer complaints or complaints from the sales function. They found that senior management were not provided with information about deliveries made or whether they were within the promised lead time. On the other hand, they found that the plants with good delivery reliability had a more proactive approach to meeting delivery promises. This consisted of holding regular production control meetings to monitor the purchases and supply of bought out items, and the co-ordination of intermediate manufacturing activities.

Britchford (1985), like Nicholson and New & Sweeney, found that one of the reasons behind the poor delivery reliability of a the single case study he investigated, was the fact that there was little monitoring of the progress of customer orders taking place. Since there was no system to monitor the progress of orders there was no way of identifying when orders had been delayed or had missed their due dates.

The writers examined in this section point to the importance of monitoring delivery reliability and also monitoring the progress of orders. There is some survey evidence to indicate that plants that monitor their delivery reliability outperform those that do not. The case study evidence, although weak, also indicates that poor delivery reliability is to some extent due to the poor monitoring of orders. The evidence indicates that companies with poor delivery reliability did not have the systems in

place to monitor progress and managers were really only aware that an order was late when it had already missed its delivery date.

2.1.4 Schedule Stability

This section will cover the issue of schedule stability which has an impact on delivery reliability. Several writers (Campbell, 1971; Gelders & Van Vassenhove, 1980, Schmitt, 1984; Chapman, 1990) considers that frequent changes to the schedule are detrimental to the manufacturing operation in that they reduce delivery reliability. Frequent changes result in an increase in the level of WIP, increased expediting of orders and can waste capacity. Schmitt (1984) and Chapman (1990) contend that a major source of schedule changes is the need to respond to changing customer requirements. Chapman proposes that a second main source of change comes from the complex internal manufacturing environment itself. The existing manufacturing complexities and frequently poor management practices often produce inaccurate databases, untimely information flows and scheduling difficulties. These conditions are aggravated by large queues, lot sizes and the numerous problems found in manufacturing relating to quality, machine downtime and other uncertainties. As the problem surfaces so the schedule is continuously adjusted in light of the latest data.

A number of studies in the automotive industry indicate the benefits of schedule stability. Oliver, Delbridge, Jones and Lowe (1994) report from their study of a number of factories in the automotive industry, that plants with low schedule variation (5 to 6%) were able to have lower finished goods stocks and were able to deliver to their customers three to four time per shift. Inman and Gonsalvez (1997) found that when a manufacturer sent unstable schedules to its suppliers it caused them to hold more inventory and also caused the schedules they send their suppliers to be more unstable. Harrison (1998) found that when supplier received a stable schedule he was able to smooth production and also hold low levels of buffer stock. These studies

certainly do show the benefits to be derived from schedule stability, however they are predominantly based on small samples taken from the automotive sector.

A number of writers have pointed to the importance of a stable Master Production Schedule (MPS) to enable plants to plan and control manufacturing operations (Berry et al, 1979; Minifie & Heard, 1986; Sridharan, Berry & Udayabham, 1987). Sridharan, Berry & Udayabham (1987) contend that frequent adjustments to the MPS caused by changes in customer order requirements, sales forecasts, or production plans, can induce major changes in the detailed MRP schedules -- creating a phenomenon often referred to as "nervousness". In their view, such changes can also lead to increases in production costs and inventory costs, and a deterioration in delivery reliability. They suggest that stability of the MPS could be achieved by freezing it over some part of the planning horizon. Simulation based research carried out by other writers found that reducing the variability of the MPS produced positive results. Bott and Ritzman (1983) investigated the impact of variation in the MPS using simulation. They found from their simulations that when the MPS stability was low then delivery reliability suffered. However when the MPS was stable, delivery reliability improved.

This section has examined the impact of schedule stability. Various writers point to the fact that poor schedule stability produces an increase in the level of inventory in the factory. Some of the research studies presented in this section indicate that poor schedule stability is linked to increased inventory levels. Some writers contend that poor schedule stability also results in poor delivery reliability. However, the research evidence to support this view is limited. What evidence there is, is based on simulations, which have limitations.

2.1.5 Production Planning and Control Techniques

There are a number of different major approaches to planning and control which can be used: Material Requirements planning (MRP); Manufacturing Resource Planning (MRPII); Just in Time (JIT) and Optimised Production Technology (OPT). The detail of how these various production and control systems operate has already been discussed at great length in the literature. This section will instead concentrate on the impact of each approach on delivery reliability:

- Section 2.1.5.1 will cover MRP/MRPII
- Section 2.1.5.2 will cover JIT
- Section 2.1.5.3 will cover OPT
- Section 2.1.5.4 will cover comparison

2.1.5.1 MRP/MRPII

MRP (materials requirement planning) originated in the early 60s in the USA as a computerised approach for the planning of materials acquisition and production (Browne, Harhen, & Shivnan, 1988)[2] . In simple terms MRP converts a discrete plan of production for a parent item into a discrete plan of production or purchasing for component items (Browne et al, 1988). This is done by exploding the requirements for the top level products, through the Bill of Materials (BOM), to generate component demand -- producing work orders and purchase orders. MRP is a simple materials and priority planning tool -- it does not check the feasibility of the master schedule (Ptak, 1991). MRPII (manufacturing resource planning) was the next step in the development on from MRP. MRPII has additional features that make it a complete planning and control system. Figure 2.5 presents the major components of an MRPII system.

[2] The classic textbook on the technique is by Orlicky (1975).

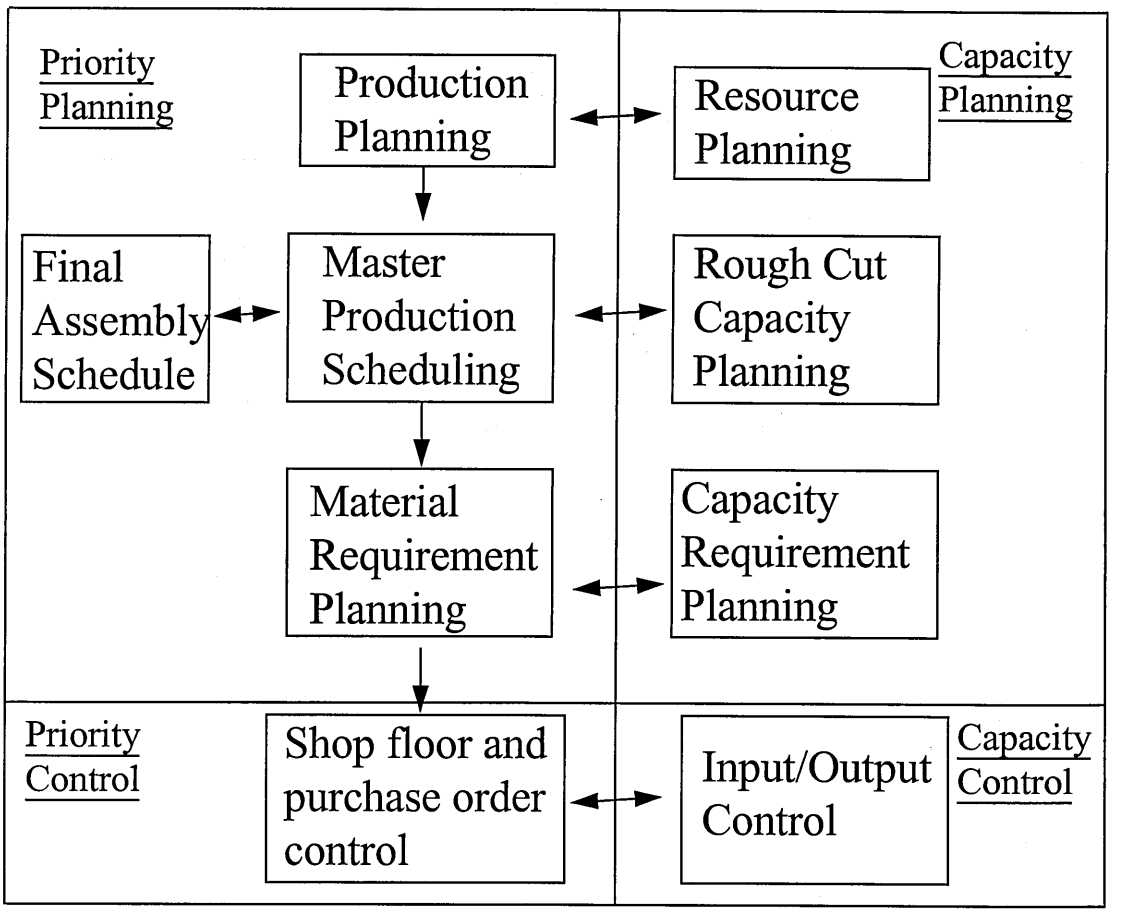

Figure 2.6: Major components of MRPII.

The complete system has four major elements to it: priority planning and control, and capacity planning and control. In brief, planning and controlling priorities ensures that products are completed when promised to the customer, and planning and controlling capacity ensures that labour and equipment are available to meet those promised due dates.

The literature indicates that the adoption of MRP/MRPII can yield improvements in delivery reliability. There are a number of case studies to indicate the improvements in delivery reliability achieved by adopting MRP/MRPII (Browne, Harhen, & Shivnam, 1988). For example, the Tennant Company increased delivery reliability from 60 to 90 per cent by adopting the system (Vollmann et al 1992). There is also some survey evidence to indicate the impact of adopting the approach. Anderson,

Schroeder, Tupy and White (1982) carried out a survey regarding the use of Materials Requirements Planning systems (433 companies stated that they had an MRP system). The study examined if a number of performance measures improved as a result of MRP implementation (Table 2.3). Their survey results indicate that inventory turnover had increased by 34%, and average delivery lead times have been reduced by 17%. They also found that the percentage of time that the plants met their delivery promises (their measure of delivery reliability) had increased by 24%.

	Pre MRP Estimate	**Current Estimate**	**Future Estimate**
Inventory turnover	3.2	4.3	5.3
Delivery lead times (days)	71.4	58.9	44.5
Percent of time meeting delivery promises	61.4%	76.6%	88.7%

Table 2.3: Operating performance of US firms using MRP (Anderson et al, 1982).

A follow-up survey was undertaken by La Forge & Sturr (1986) of MRP usage in South Carolina (using the same questionnaire as Anderson et al). Table 2.4 shows the operating performance of the MRP users (only 33 companies were MRP users).

	Pre MRP Estimate	**Current Estimate**	**Future Estimate**
Inventory turnover	4.5	7.9	11.2
Delivery lead times (days)	55.6	41.7	31.8
Percent of time meeting delivery promises	73.9%	88.8%	94.6%

Table 2.4: Operating performance of the firms in the La Forge & Sturr (1986) study.

La Forge and Sturr conclude that their results confirm the findings of the study by Anderson et al, namely that the adoption of the MRP system did bring business benefits.

It would appear from the results of the Anderson et al study and the La Forge & Sturr study that MRP does bring some major business benefits to manufacturing organisations, in particular an improvement in delivery reliability. However, the studies suffered from the drawback that the operating performance is estimated rather than actual recorded performance, so there is a possibility that the estimates given may have been optimistic, and so may have biased the results.

There have been surveys of MRP use in other countries. Sum and Yang (1993) carried out a study of manufacturing resource planning (MRP & MRPII) of 59 users in Singapore. The authors found that the major benefit of introducing the system was improved delivery performance followed by improved production scheduling. However, the study suffered from the drawback that the questionnaire they used asked the respondents to rank a series of benefits (using a scale of 1 to 5) rather than provide actual performance data. Consequently the study shows the perceived benefits of the system, rather than its actual benefits.

2.1.5.2 Just in Time

The JIT production philosophy was developed at the Toyota Motor Company (in Japan) during the 1960s and is currently in use in a variety of industries across the world. Just in time is a philosophy covering all aspects of a manufacturing operation with the aim of producing the required items, with perfect quality, in the required quantity at the precise time required (Brown, Harhem & Shivnan, 1988). A number of case studies have pointed to the fact that the adoption of JIT results in reduced inventory levels, reduced throughput times and increased productivity (Aggarwal, 1985; Sohal & Howard, 1987). Overall, most of the benefits reported have tended to concentrate on inventory reduction and throughput time reduction (Sohal & Howard, 1987; Golhar & Stamm, 1991). However, there is some survey evidence indicating the impact on delivery reliability.

Cheng's (1988) survey of JIT production in the Hong Kong electronics industry found that 23% of respondents stated that the major benefit of JIT was that it ensured on-time delivery. The limitations of this study was the sample size; only 20 companies completed the questionnaire.

Nakamura, Sakakibara and Schroeder (1998) studied the impact of the adoption of JIT manufacturing methods at US machinery, electronics and automotive component plants. They found the JIT technique did improve manufacturing lead times and quality levels. They found that the adoption of JIT only marginally (the results were significant at the 10% level) improved the level of delivery reliability (percent of orders that were shipped on time). However, their study suffers from the problem that it is based on a small sample of only 40 plants. Also the results are limited to the machinery, electronics and automotive industries.

2.1.5.3 OPT

Optimised production technology (OPT) is another production control philosophy. The primary goal of OPT is to make money through increasing plant throughput (sales) while simultaneously decreasing inventory and operating expenses (Larsen & Atting, 1993). The OPT system calculates the near optimum schedule and sequence of operations for all a manufacturing company's work centres, taking into account priorities and capacities (Aggarwal, 1985).

There have been some successes with OPT reported, Wheatley (1986, 1989) reports that STC, the first European company to implement the system, saw work-in-process inventories fall, lead times reduce and the late deliveries of finished products fall to only 30 percent of the pre-OPT levels. He also reports that other companies have had success with OPT but no mention is made of whether it improved delivery reliability.

2.1.5.4 Comparison of Techniques

The previous sections (sections 2.1.5.1 to 2.1.5.3) have examined the impact of the various approaches, to production planning and control, on delivery reliability. The literature indicates that the use of the various approaches can lead to improved delivery reliability. However, a question that remains unanswered is which method produces the highest level of delivery reliability? The research of Newman and Sridharan (1992) attempts to provide an answer. They surveyed Ohio manufacturing facilities to determine which of a number of production planning and control approaches were being used and how well the firms using them were performing. The majority of the firms (165 facilities completed the questionnaire) reported using MRP-based systems (56%), followed by Re-order point based systems (22%). A much smaller number reported using JIT (8%) or OPT based systems (5%). Table 2.5 shows the average levels of performance being achieved for each of the approaches used. The authors make the comment that, overall, no one system dominated across all the performance criteria.

Performance Measures	MRP	JIT	OPT	ROP
Inventory Turns	19.1	13.4	27.6	9.9
On-time delivery (%)	83.0	88.7	86.2	85.2
Delivery lead time (wk.)	8.4	9.1	11.6	6.7
Lateness (wk.)	1.7	2.6	2.4	1.8
Utilisation (%)	76.0	82.8	74.3	79.1

Table 2.5: Performance by system (Based on Newman & Sridharan, 1992).

If we examine delivery reliability (on-time delivery), we find that JIT users enjoyed the highest level of performance and the MRP users the lowest level. However, the results show the rather interesting fact that although plants with JIT reported higher average on-time delivery reliability, they also had the longest average lateness. This is

a result we would not expect to find for plants with high levels of delivery reliability. The results may have been impacted by the small number of JIT users. Also the authors did not indicate if the performance data presented was based on perceived or actual recorded performance. Therefore the results of this survey should be treated with caution.

The various sections have pointed to the fact that each of the various major approaches to planning and control can lead to improved delivery reliability. However, there has been little research carried out to indicate which approach produces the highest level of delivery reliability. The issue of which approach to production planning and control yields the best results still needs further research.

There are two other major areas of literature associated with production planning and control that need to be covered at this stage. The two areas are dispatching rules and order review and release. The next section (2.1.5.5) will cover dispatching rules, while the following section (2.1.5.6) will cover order review and release.

2.1.5.5 Dispatching Rules

A dispatching rule is used to select the next job to be processed (to help with priority control), from a queue of jobs waiting at a work centre (Hendry & Kingsman, 1989). The dispatching rule used can be as simple as 'select a job at random'. While the rules determine which job to process next, they do not as Hendry & Kingsman (1989) point out, provide a schedule of jobs through the shop.

There are numerous dispatch rules, (Panwalker & Iskander (1977) identified more than 100) however the most common are as follows:

- Shortest processing time (SPT)
- First-come, first served (FCFS)

- Due date of job (DDATE)
- Slack per remaining operation (S/OPN)[3]

The research on dispatching rules (which is predominantly based on simulation studies of job shops) has examined the impact of various rules on due date performance (in terms of lateness). The measurement criteria most often used for studying the effectiveness of dispatching rules are flowtime, lateness and tardiness (Blackstone et al, 1982). These can be defined as:

- Flowtime (Fi) - The total time the job spends in the system
- Lateness (Li) - the amount of time by which the completion time of a job exceeds its due date.[4] (Lateness may be negative indicating that the job was completed early).
- Tardiness (Ti) - The positive lateness of a job (Ti = max. 0, Li)

Conway & Maxwell (1962) found from their computer simulations of a simple single server environment that the SPT (shortest processing time) rule was found to minimise the mean flow time (and so maximise throughput) and also minimise lateness (thereby helping to ensure high delivery reliability). They extended their simulations to the multiple machine environment and found that the SPT rule minimised the mean flow time. However, while few jobs were late with the SPT rule, those that were, were very late (the standard deviation of lateness was very long).

For a more extensive and in-depth discussion about which rules perform best under different criteria and different shop environments the reader is recommended to consult Blackstone et al (1982).

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[3] slack per remaining operation = (Due date - time now) - (Remaining machine involvement time)/Number of operations to be done.

[4] Lateness Li = (Actual flow time through shop - Total time allowed for job to pass through shop) where time allowed = Due date - Issue date
So a negative value for Li indicates that the job finished early. A job is tardy only if Li=>0 in which case Ti=Li otherwise Ti=0

The research on dispatching rules has been prolific and extensive (Blackstone et al, 1982), however it has a number of weaknesses. It has been entirely based on mathematical formulae that cannot truly model the complex dynamic situation found in a plant. Also, some of the assumptions made such as facilities do not breakdown or the splitting of jobs does not happen, do not reflect the real world where such things do happen. Constable & New (1976) make the point that the dispatching rules are concerned with making local decisions (usually a work centre) to achieve global objectives such as achieving due dates. Using local decisions to achieve global objectives may not produce the optimal results required. Green and Appel (1981) make the important point that it is very difficult to compare the relative performance of the different rules because of the variations in the job shops simulated, with respect to arrival patterns, assumptions used, conditions simulated and so on. Tatsiopoulos and Kingsman (1983) state that research suggests that sophisticated dispatching rules should not be used because they interrupt the natural flow of work in the shop and add more problems than they solve.

2.1.5.6 Order Review and Release

The order review and release concept is the process whereby the production orders are scanned (prior to release onto the shopfloor from the pre-shop pool) and a decision is made about which ones are allowed to be released to the shopfloor, at which time and under what conditions they are to be released (Melnyk, Denzler & Fredendall, 1992). The concept tries to level load by smoothing the flow of work on to the shopfloor so it is more in tune with the current state of capacity utilisation. The main objective of the approach is to control WIP level and workload balance both among machine centres and overtime. A number of writers (Bechte, 1988; Hendry & Kingsman, 1991; Wiendahl, 1987, 1995) claim that order review and release will achieve better balanced workloads among the work-centres, thus achieving better utilisation and

throughput rate together with improved manufacturing lead-times and delivery reliability.

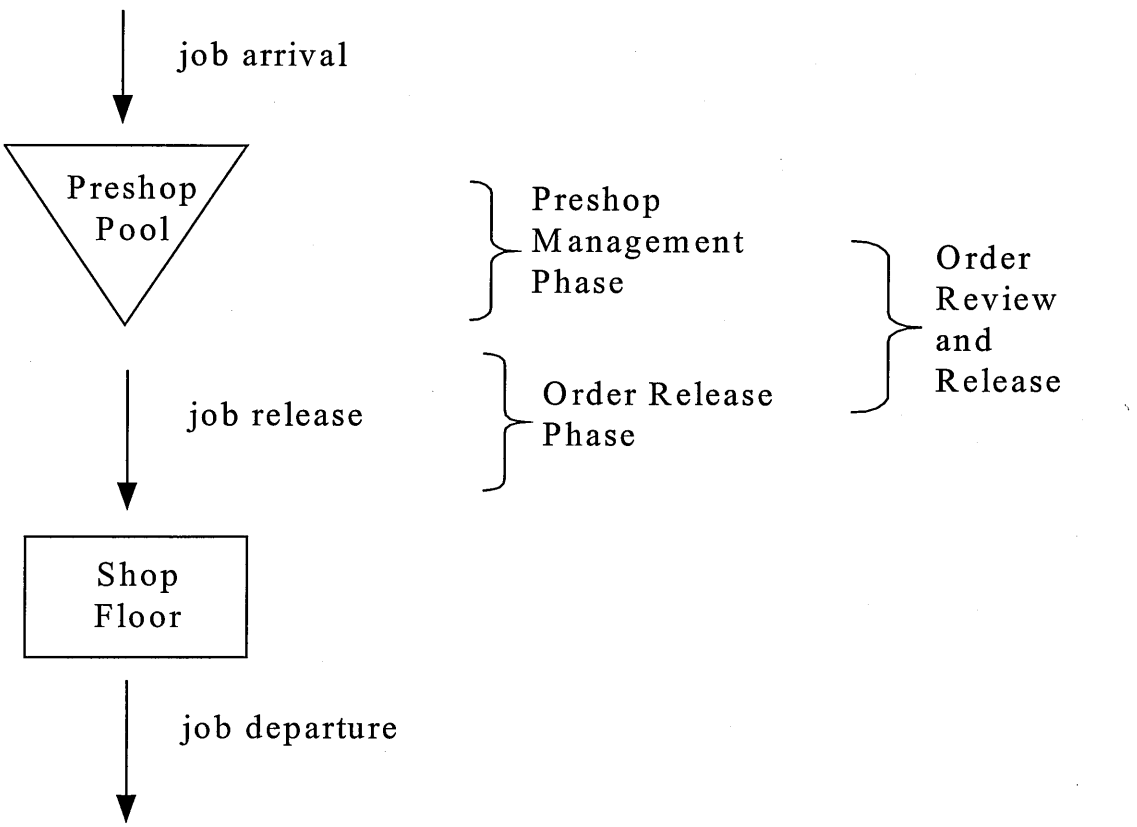

Figure 2.7: Simplified diagram of the order review release (based on Bergamaschi et al, 1997).

The major basic mechanism by which researchers have attempted to control the shop's work load is by the limitation of load released to the shop. This principle of limiting the load that is allowed to enter the shop is the basis of Bechte's work (1988, 1994). He presents a technique aimed at controlling lead times by setting limitations to the WIP inventory at each work centre, the load released to the shop is controlled so that the limits are not breached, thereby ensuring that the system is not overloaded and manufacturing lead times increase. Wiendahl (1987, 1995) takes a similar approach to that of Bechte. By controlling the load of the work on the system, the

adjustment of a defined inventory level of a job shop is possible. Since this inventory corresponds with a certain lead time, the system realises lead time control (lead times are fairly constant) and ensure on-time delivery.

Bergamaschi, Cigolini, Perona & Portioli (1997) in their review of the order review literature came to the general conclusion that all the simulation work suggested that the adoption of an order review and release procedure can have several beneficial effects on the shops, including reduced stock carrying costs, shop congestion and flowtimes. However, Kanet (1988) argues that limiting the release of jobs to the shop does not reduce WIP and mean flowtime. He argues that if arrival times and process times remained unchanged then holding jobs in a release pool (pre-shop pool) will not influence the mean flowtime (if the mean flowtime is defined as the time in the release queue plus the actual time in the shop). The variability in the manufacturing lead times may be reduced but the total manufacturing lead time is still the same.

The research to support the order review release approach suffers from the drawback that it is predominantly based on simulation studies (Wisner, 1995; Bergamaschi et al, 1997). Wisner (1995) in his review of the research in the order release area, admits that there is a lack of empirical research concerning the experiences of firms using order release. In addition as Hurley (1992) points, the approach suffers from the theory-practitioner gap in production scheduling theory. As he points out, to operate the approach, the WIP content of each work centre would need constant monitoring, a requirement not necessarily easy to achieve in some factories.

2.1.5.7 Additional Research

There are a number of additional research surveys relating to delivery reliability that need to be covered at this stage. Young, Kwong, Li and Fok (1992) examined the manufacturing practices of manufacturing companies in two industry sectors (small machine tools and non-fashion textiles) in China, Korea, Japan, Western Europe and

the USA (using data from the Global Manufacturing Research Group).They examined the reasons for orders being late. The respondents were asked to list the two most common reasons for orders being late, Table 2.6 shows their findings.

	Percentage Responding				
	China	**Japan**	**Korea (S)**	**Europe**	**USA**
Machine Tools					
Machine capacity	25	39	39	12	9
Lack labour capacity	41	28	22	32	29
Product bottleneck	9	44	13	47	29
Transportation	11	0	0	35	0
Material Shortages	34	11	25	26	51
Quality problems	16	17	44	9	29
Due-date changes	23	33	13	21	9
Other	20	0	0	0	31
Textiles					
Machine capacity	11	36	39	8	32
Lack labour capacity	50	11	15	46	24
Product bottleneck	25	36	15	33	38
Transportation	70	0	0	42	2
Material Shortages	32	28	18	38	48
Quality problems	16	17	45	17	20
Due-date changes	7	83	9	17	8
Other	11	28	0	0	10

Table 2.6: Most Frequent Causes of Late Orders (based on Young, Kwong, Li and Fok, 1992).

Table 2.6 shows that the European machine tool industry highlighted product bottleneck and transportation as the main causes of late orders. While in the case of

textiles they indicated a lack of labour capacity and transportation as the main reasons. Transportation did not feature very highly as a cause of late orders for the Japanese, USA or Korea companies. In the USA the main problem, for both the machine tools industry and the textile industry, was material shortages. The research undertaken by Young et al points to a number of factors that appear to cause late delivery of orders in two industry sectors. However, their research is limited because they only asked the respondents to list only two causes and it does not indicate the strength of the influence on late delivery of the chosen factors.

Lindberg and Trygg (1991) study of Swedish manufacturing companies identified that the reasons for poor delivery reliability were due to: ineffective manufacturing control system, long lead times, scrap, and inability to produce to high quality standards. However, their research suffered from the problem of a small sample size (only 26 companies).

Handfield and Pannesi (1992) carried out a study into manufacturing plant delivery reliability. Their sample consisted of 285 US firms (of which 193 employed job-shop or batch-flow processes). They were of the opinion that in determining schedules and setting due dates for delivery the critical planning activities that take place are forecasting demand, planning production, planning inventories and setting the master production schedule (see Figure 2.8). They found that production plan performance (percentage of plan achieved), inventory goals met and master schedule performance (per cent of schedule achieved) all had a significant positive effect on delivery reliability.

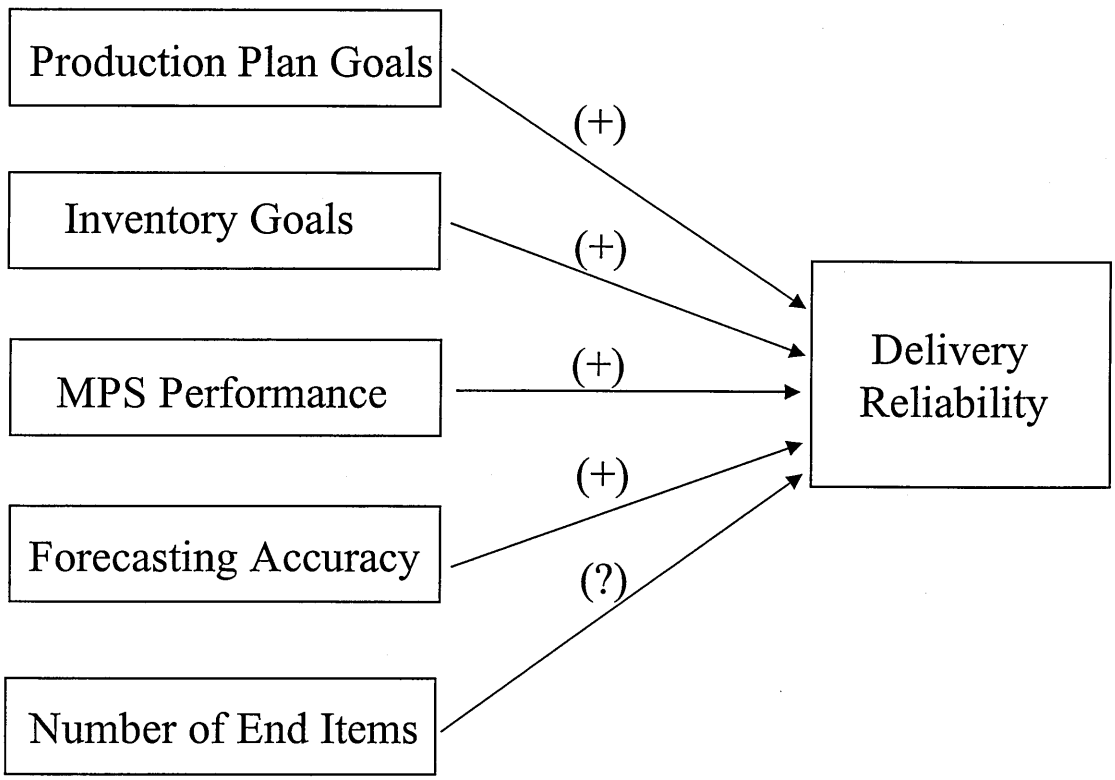

Figure 2.8: Factors that impact delivery reliability (Handfield & Pannesi, 1992).

However, the level of forecasting accuracy did not have an effect on delivery reliability. They also found that the number of end items (but excluding spare parts) were also positively related with delivery reliability. In the authors view a firm striving to improve delivery reliability in a job-shop or batch environment should focus on developing sound production and inventory goals and realistic master schedules. Their results appear to support the views of the writers who point to the need for producing a realistic master production schedule. The results were based around what the plants considered to be their delivery reliability, in some cases this may have been monitored (actual delivery reliability) but in some it may not have been (purely on estimate); it is difficult to determine from their paper what was actual and what was estimated delivery reliability.

Wacker and Hanson (1997) investigated the performance of manufacturing plants world wide. They found from their regression analysis that the use of MRP and CRP

(Capacity Requirements Planning) improved delivery reliability. They also found that the use of dispatch rules did not impact delivery reliability, and an increase in engineering changes caused a decline in delivery reliability. Unfortunately, it is difficult to analyse their research because their paper does not give enough detailed information (in particular the regression equation and actual sample sizes) to make this possible.

De Meyer and Ferdows (1990) investigated the influence of manufacturing improvement programmes on performance using the European Futures Data. The data comes from a sample of large European manufacturing organisations who were asked to complete a survey. The respondents who complete the questionnaire tended to be Directors. De Meyer and Ferdows examined the relative emphasis (using Likert Scales) placed on a series of action programmes (36 to 39 in total) for a three separate years 1986, 1987 and 1988. They also took a second set of data referring to the reported changes in eight performance measures between 1985 and 1988[5]. They examined the relationship of intended action programmes (as the independent variable) and the reported performance (as the dependent variable). They found that on-time delivery was positively influenced by better purchasing, integration of information systems, capacity expansion or plant relocation, while quality circles and CAD had a negative effect. The problem with their research is that they are using aggregate data and not information about individual plant's performance. They also used delivery reliability data that was based on perceived rather than actual performance.

Voss and Blackmon (1996) investigated the difference in the practice and performance of UK and German manufacturing sites using their PROBE database. They found that overall their was no significant difference in the overall performance of UK and German manufacturing sites. However, they did find that German manufacturing sites had significantly higher delivery reliability performance than UK sites. They attributed the superior performance of the German sites to better practices with regard

to automation and information systems, which delivered improved scheduling and order tracking abilities. While Voss and Blackmon attribute the superior performance of the German sites to these factors they offer no empirical evidence to back up their contentions.

However, their research findings suffer from more fundamental limitations. Some of the questions used in the questionnaire are biased towards certain industries (New & Szwejczewski, 1995). The questionnaire scores the sites on various questions, relating to either practices or performance. Each question has a scale of 1 to 5 (where 5 is considered "world class" performance or practice). So, for example their question which refers to delivery reliability has the scoring method outlined in Figure 2.9.

Score	1 2	3	4 5
Customer delivery commitments met	Less than 80 per cent per month	More than 95 per cent every week	More than 95 per cent every day

Figure 2.9: Scoring approach used by Voss & Blackmon (New & Szwejczewski, 1995).

It is generally accepted by most major food manufacturers in the UK that if you do not supply the major supermarket chains at 99 per cent plus you are not likely to supply them for very long, and this is generally accepted as the industry standard. However this level of performance still does not guarantee being a "world class" food manufacturer (which is what a score of 5 is supposed to indicate). Similarly, to score (for example) an aluminium rolling mill "1" because its scrap, rework or recycle costs are more than 10 per cent of product cost while giving the food manufacturer "5" if this is less than 1 per cent completely ignores the nature of the industry and its technology. An objective appraisal of the scoring system shows a bias towards food,

[5] The performance measures were based on index numbers, rather than real monitored and reported performance information.

electronics, short cycle manufacturers and simple products, and against complex mechanical engineering and aerospace manufacturing. Given the problems with this aspect of their research methodology their results should be treated with care.

In summary, additional research has indicated some of the variables that may lead to better delivery reliability. Handfield and Pannesi found that product plan performance, inventory goals met and master production schedule performance had a significant positive effect on delivery reliability. The work of De Meyer and Ferdows indicated that improved purchasing, the integration of information systems and capacity expansion were positively related to delivery reliability; while Wacker and Hanson found that the use of MRP and CRP produced improved delivery reliability. However, there is still need to examine further which variables impact delivery reliability.

2.2 PRODUCTION

This section covers the second major group of literature shown in Figure 2.1. The section examines the various factors that may impact delivery reliability when the product is being manufactured. Delivery reliability can be impacted by the during manufacture. Delays at any one stage of the production process may result in further delays at consequent stages of production, with the overall effect that the delivery date is missed.

Several writers (e.g. Slack, 1991; Kochhar & McGarrie, 1992; Andries & Gelders, 1995) point to the possible detrimental impact of machine breakdowns. Machine breakdowns destroy the smooth running of the factory and the predictability of the manufacturing operation. The delays in production caused by machine breakdown also means that manufacturing lead times may increase with the result that due dates are missed. Slack (1991) states that machine breakdowns produce poor internal dependability. For him, poor internal dependability can play havoc with schedules,

because a plant has to be rescheduled on a continuous basis because it failed to produce all the items scheduled previously.

Kochhar (1982) and Andries & Gelders (1995) make the point that machine breakdowns reduce plant capacity, directly in the case of a bottleneck machine and indirectly if it causes starvation of bottleneck machines. They suggest that breakdowns also create a lumpy material flow that results in WIP concentrations at some places and starvation at other places. Kochhar and McGarrie (1992) study of seven manufacturing operations found that machine breakdowns led to greater uncertainty in the factory. Their research indicated that machine breakdowns made shop floor control more difficult.

Other factors can also cause delays. Slack (1991) and Andries & Gelders (1995) point to the detrimental impact of material and part shortages, while Ashton & Cook (1989) indicate that poor quality parts and the non-availability of labour will produce delays and disrupt the production schedule. Kochhar (1982) points to the fact that absenteeism can lead to a reduction in the capacity available. Britchford (1985) suggested that one of the reasons for his case study plant's poor delivery reliability was the high failure rate at final test (1 in 13). He commented that the high level of rework and re-testing caused considerable disruption to the flow of production, increased the size of WIP and led to numerous late deliveries.

Several writers point to the importance of having up-to-date information about the status of jobs in the factory (Holstein, 1968; Kochhar, 1982; Nicholson, 1989). Holstein contends that a lot of the production management's problems are caused by a lack of up-to-date information on the status of jobs in the factory. It is important to know the location of a job, whether it is ahead or behind schedule and what work remains to be done. Without accurate data the task of ensuring that the correct orders are being worked on and that they achieve their delivery dates becomes much more difficult.

It is not just accurate information about the status of a job that is important. Kochhar (1982) also makes the point that both production and planning need accurate and up-to-date data to work effectively.

Maani, Putterill and Sluti (1994) investigated the impact of quality improvement on manufacturing performance. They investigated the importance of quality improvements amongst Australian companies over a three year period. They found that improvements in quality resulted in improvements in delivery reliability. Their research suggests some interesting results, however it suffered from the problem that their results were based on perceptual measures of performance rather than actual data.

The literature indicates that delays during production may result in some cases manufacturing lead times becoming longer; the literature suggests that the variability of the manufacturing lead times may increase. In the early part of this chapter I indicated that another reason for an increase in the variability of manufacturing lead times, they could increase as a result of the overloading of the manufacturing plant. Some writers suggest that there are other factors that produce increased variability. Heard & Plossl (1984) contend that a major source of manufacturing lead time variability is ineffective engineering practices. They suggest that a number of areas produce lead time variability. Poor plant layout results in orders moving long distances in a snaking movement. When combined with layout problems and highly fragmented routings it creates unnecessarily long lead times and high lead time variability. Long set-up times and large lot sizes can also have an impact. With large batches work tends to arrive at work centres in large clumps at infrequent intervals, while long set-ups result in high work-in-process which leads to excessive and variables lead times.

Wacker (1987) examined the relationship between manufacturing goals and internal plant throughput time. He presents a mathematical model of internal throughput time that is separated into two elements - non processing and processing time.

These were made up of several elements in turn:

a) Non processing time
   - move time
   - queue time

b) Processing time
   - set-up time
   - preventative maintenance time
   - run time
   - rework time
   - machine downtime
   - stockout time

Wacker concludes from his model that reducing the variability of move time and processing time are one of the ways of improving the manufacturing systems performance - in particular delivery reliability. He states that the managerial implications are clear - controlling move time, preventative maintenance, machine downtime and rework, and removing the reasons for the variation are necessary for the manufacturing system to be predictable. He states that on-time delivery reliability can be improved by the reduction of variability and by shortening throughput time. He also feels that any improvement in internal quality will lead to improvements in throughput time and consequently led to improvement in delivery reliability. Wacker provides some interesting results, however he offers no other research evidence to support his model. In addition, as Harrison (1995) points out, Wackers result's are hardly surprising given his original set of assumptions.

The writers presented in this section offer various factors that may cause delays in production. Delays in production caused by machine breakdowns may destroy the smooth running of the factory producing an increase in manufacturing lead times and ultimately a decline in delivery reliability. Material and part shortages, poor quality and the non-availability of labour can also produce delays and may also result in missed delivery dates. However, these statements are mainly based on experience, anecdotal or case study evidence.

This section also examined manufacturing lead time variability. The writers pointed to several factors, such as poor layout and long set-up times, as well as poor quality and machine breakdowns that produce increased variability. The literature suggests that a reduction in manufacturing lead time variability helps to ensure good delivery reliability. However the assertions made in the literature are based on mainly anecdotal evidence or conceptual models.

2.3 SUPPLY CHAIN MANAGEMENT

Once the customer's order has been manufactured it still needs to be delivered to the customers premises, which is where the whole issue of supply chain management comes in. Supply chain management is a growing area of academic and practitioner interest. Supply chain management has been defined as an integrative philosophy to manage the total flow of a distribution channel from suppliers through to the ultimate end user (Houlihan, 1985; Jones & Riley, 1985; Houlihan, 1988; Steven, 1989; Oliver & Webber, 1995). The scope of supply chain management is shown in figure 2.10.

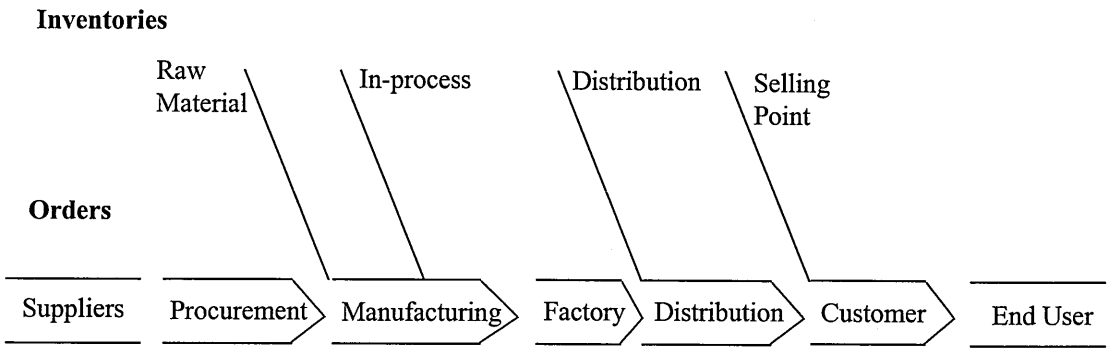

Figure 2.10: The scope of supply chain management (based on Oliver & Webber, 1995)

The primary objective of supply chain management is to achieve the most cost effective satisfaction of end customers requirements through the buyer-supplier process integration (Christopher, 1992). The buyer-supplier integration means that the supply chain must be analysed and managed as a single entity (Houlihan, 1985: Jones & Riley, 1985; Battaglia & Tyndall, 1991). This is fundamental to the concept of supply chain management and is not limited to the integration of functional departments within the organisation, but extends to all the firms in the supply chain (Ellram & Cooper, 1990). Without such integration, management of the supply chain is fragmented and therefore the potential benefits of supply chain management are not possible.

Supply chain management focuses on the control and management of inventory and information throughout the entire supply chain, from the supplier to the ultimate customer. The approach looks across the entire supply chain, rather than one element, in an attempt to manage supply chain inventory (Houlihan, 1988; Ellram & Cooper, 1990). The concept focuses attention on holding inventory in the location and quantity that is optimal for the entire supply chain. In order for this to be done, timely and accurate information is needed from key players throughout the supply chain regarding the quantity, quality and timing of inventory needs. Information is a key balancing agent, exchanging information for inventory and thereby reducing the risk

of uncertainty and the levels of inventory in the supply chain (La Londe, 1984; Ellram & Cooper, 1990). Ellram & Cooper (1990) state that suppliers, customers and third party providers share information and plans necessary to make the channel more efficient and competitive and also to improve total system performance. A key element of this is the forming of partnerships across the supply chain. Such partnerships or relationships must be based on trust and the sharing of information and a recognition by all the parties that they are mutually dependant on each other (Spekman, 1988; Ellram & Cooper, 1990). Maltz and Maltz (1998) found from their investigation of the medical equipment, and industrial equipment that when a high level of information exchange was taking place the level of late delivery was reduced.

Writers on supply chain management have pointed to a number of benefits (e.g. Houlihan, 1985; Jones & Riley, 1987; Ellram, 1991; Guinipero & Brand, 1996). The approach is said to deliver improved service levels to the end customer at a lower overall cost (one component of this improved service is delivery reliability)[6]. The second benefit that supply chain management is considered to deliver is faster throughput times across the whole supply chain. Short process and throughput times across the supply chain guarantee the ability to react quickly and productively to changing end-customer demand.

Guinipero & Brand (1996) investigated what purchasing managers saw as the benefits of supply chain management. They carried out a survey of purchasing managers (their sample of 58 ranged from Purchasing Directors to Purchasing Managers). The respondents were asked to rate the potential benefits of supply chain management (14 benefits were listed). The respondents considered the improved co-ordination with their suppliers to be the most important benefit. The next five most important benefits were: reduced lead times, greater productivity in their operations, lower inventories, improved delivery reliability from suppliers and lower product costs.

[6] There is a tendency in the supply chain literature to consider delivery reliability to be one element of customer service (Maltz & Maltz, 1998; Mentzer et al, 1989). Consequently it is seldom examined on its own.

Spekman, Kamauff and Myhr (1998) studied a number of aggregated supply chains in America, and Europe. They found that the various players in the chain in the main considered the main benefits of supply chain management was increased end user satisfaction by improvements in various elements of customer service, one of which was delivery reliability. However, the study does not tell us how to improve delivery reliability.

Demand amplification is a major problem in supply chain management (Towell, 1996; Harland, 1996). Forrester (1961) identified the fact that demand information about timings and volume of requirements from customers downstream in the supply chain, become increasingly distorted further upstream in the supply chain. This distortion is caused by time delays in ordering, batching of information and of requirements, safety stock provision, problems in communication and inaccurate forecasting. The resulting "Forrester Effect" is an increasing amplitude of perceived demand which causes lumpy and irregular schedules in upstream businesses and the possible impact on delivery reliability. The work of Burbidge (1961) also shows the impact of demand amplification. A number of writers suggest that organisations need to strive to overcome the impact of demand amplification if they are to achieve the potential benefits of supply chain management (Towell, 1996, Christopher, 1992).

The supply chain management concept has received growing attention and recognition over the last decade. However, it is still in its emerging phase of development. As Guinipero & Brand (1996) point out, the literature deals primarily with definitions of the concepts. Guinipero and Brand also make the point that the supply chain management literature contains little empirical study. There is no evidence to indicate if delivery reliability improves throughout the supply chain due to the adoption of supply chain management.

To better understand which factors impact delivery reliability we need to move from the overall system down to the component level and look at two important elements: suppliers and transportation.

2.3.1 Suppliers

Most manufacturing companies need to obtain raw materials and/or components from external suppliers in order to make the final product required by the customer. Figure 2.11 illustrates the fact that suppliers provide inputs to the manufacturing process at a lot of stages and not one point.

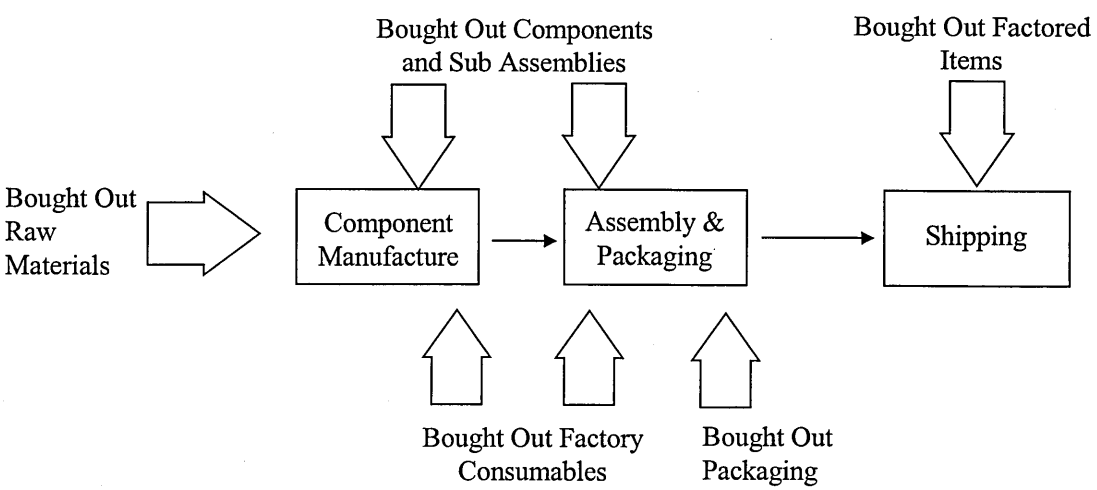

Figure 2.11: The various points where inputs from suppliers arrive.

Several writers (Paulden, 1977; Corke, 1978; Burt, 1989; Handfield, 1993; Handfield & Pannesi, 1995) suggest that a delay on the part of the supplier may mean a delay in the production of the customer order and possibly a failure to deliver on time.

Late delivery by suppliers is a problem that a number of manufacturing plants have to face. Toone (1981) found in his study of East Midlands manufacturing companies that 30% of the companies did not know by how much purchased materials were late and only 35% of the companies could say with certainty that they had better than 90% on-

time delivery from their suppliers. Vondermebse, Tracey, Tan and Bardi (1995) found from their study of US manufacturing companies that on-time deliveries from suppliers had improved, while work stoppages due to the non-availability of raw materials had declined. However, these research studies did not examine if the late delivery actually had an impact on a company's delivery reliability.

Cunningham & Dale (1983) investigated the effect that the delivery reliability of 16 suppliers had upon a manufacturing company. They found that the company suffered from poor supplier delivery reliability, 60% of the supplier orders were delivered late. The average lateness of orders was 1.82 weeks. The authors offered a number of reasons for poor supplier delivery reliability. Firstly, there was an unrealistic pressure put on suppliers for early delivery (in the case of 59% of the orders the company requested a lead time that was shorter than that quoted by the supplier). Secondly, the suppliers had taken on more orders than they had the capacity to complete. Thirdly, the suppliers tended to let more profitable or otherwise valued orders jump the queue. Fourthly, the suppliers' internal control of the flow of orders was inadequate to ensure that they were finished on schedule. Cunningham and Dale found that the company itself had less than one week of production in arrears. This was an interesting result because 50% of the suppliers delivered more than 4 weeks late. So how did the company achieve such low levels of arrears? Well, quite simply, the company had resorted to breaking down semi-finished machines and sub assemblies on works orders with a later date in order to satisfy the more urgent orders. The poor supplier performance had not only resulted in the company's' delivery reliability suffering, it had also increased the cost of expediting and increased confusion on the shopfloor.

Britchford (1985) identified, from his case study research into the delivery reliability of an engine manufacturer, that one of the reasons behind the manufacturers poor delivery reliability was late deliveries by suppliers. He states that large numbers of component shortages in the plants were due to the poor delivery reliability of the suppliers.

The research of Britchford and Cunningham & Dale shows that suppliers delivery reliability can impact plant delivery reliability. Poor supplier delivery reliability can result in poor plant delivery reliability. However their research results do not conclusively prove that such a relationship exists since they are based on single case studies.

This section has examined the impact of suppliers on delivery reliability. Late delivery by suppliers is considered by writers to delay the production of customer orders and may result in poor delivery reliability. The case study evidence does in fact suggest that poor delivery reliability can result from poor supplier delivery reliability. However, the research has the limitations of being based on single case studies.

2.3.2 Transportation

If manufacturing manage to make the product by the due date, this is not the end of the story. The internal delivery date may have been hit, the plant's internal delivery reliability may be good, but the product still has to be transported to the customer (as the model proposed by New and Sweeney indicates, see Figure 2.5) and it may still be possible for delays to occur at this stage and for the delivery of the product to the final customer to be delayed.

Paulden (1977) points to a number of factors that may cause delay in transportation of products, especially to overseas destinations:

- Incorrectly completed or missing documentation that accompanies the product. The order may be delayed by customs because some information is missing or incorrectly completed.
- Poor understanding of export and transit procedures.

- Poor management of the shipping agents. It is important to state the date the product is to be delivered to the customers door and the specific location that the product is to go to.

Davies and Gray (1980) point to the fact that when the delivery date quotation is first determined care should be taken to calculate the transportation time from the factory to the customers' premises. Extra care should be taken when exporting products, since total transit times do vary between nations (partly caused by custom delays).

Lee & Billington (1992) point to several pitfalls (based on their own experiences) of managing the supply chain. Some of these pitfalls, if not dealt with, result in poor delivery reliability.

- Ignoring the impact of uncertainty. Supply chain managers need to understand the sources of uncertainty and the magnitude of their impact. A lot of companies now monitor their supplier delivery reliability, but very few know about transit times specifically from distribution to their customers. All too often when an order leaves their dock, management considers their job is done but the order still needs to arrive at the customers premises and while transportation lead times have been reduced, there still exists variability in these delivery lead times.
- Poor co-ordination. If the customer order consists of multiple items that are supplied by different divisions and if the customers demand receipts of all items at the same time the company will use a merge centre. The products will be shipped to the customer as soon as they all arrive - tight co-ordination at this stage is important. A lack of co-ordination in this process results in excessive delay and poor delivery reliability.

This section has covered the issue of transportation of the order to the customer. A number of writers have pointed to the various factors that may result in delays in transportation which may ultimately result in late delivery to the customers premises.

However, the assertions made by the writers are based mainly on personal experience or anecdotal evidence. This area needs further research.

2.4 CONCLUSION

This chapter has examined the first half of the literature (operational) relating to delivery reliability. The review of the literature indicates that several areas are important to ensuring high levels of delivery reliability. It indicates the importance of balancing load and capacity. When the load exceeds capacity manufacturing lead times increase and become more variable and ultimately delivery reliability suffers. The literature also points to the importance of the quotation stage to ensuring good delivery reliability. The way to arrive at a realistic delivery date is to take into account the load and capacity of the plant when determining the delivery date. Some writers suggest the department that should be responsible for providing the delivery date quotation is the production planning department. This is because they have the necessary information about load and capacity to ensure that a realistic delivery date is provided.

A number of writers stress the importance of monitoring delivery reliability. They also indicate the need to monitor the progress of orders through the factory.

Delays in production, due to the impact of machine breakdowns, can result in poor delivery reliability. Delays in production can also be due to material and part shortages. The delays can also lead to increased manufacturing lead time variability. Delays in production, for whatever reason, are also a reason for the importance of monitoring the progress of orders. The literature also points to the fact that poor supplier delivery reliability can result in poor plant delivery reliability.

However, even if the product has been produced by the manufacturer on-time, it still needs to be delivered to the customer premises. Delays in the transportation of the

product to the customer can result in the customer not getting their order delivered to them on time.

Just as operational factors impact delivery reliability, so do a range of contextual factors, such as complexity. This contextual element of the literature will be reviewed in the next chapter.

CHAPTER THREE

LITERATURE - CONTEXTUAL FACTORS

3.0 INTRODUCTION

While Chapter Two covered the operational factors, Chapter Three will examine the contextual factors that are considered to impact delivery reliability (as shown in Figure 3.1).

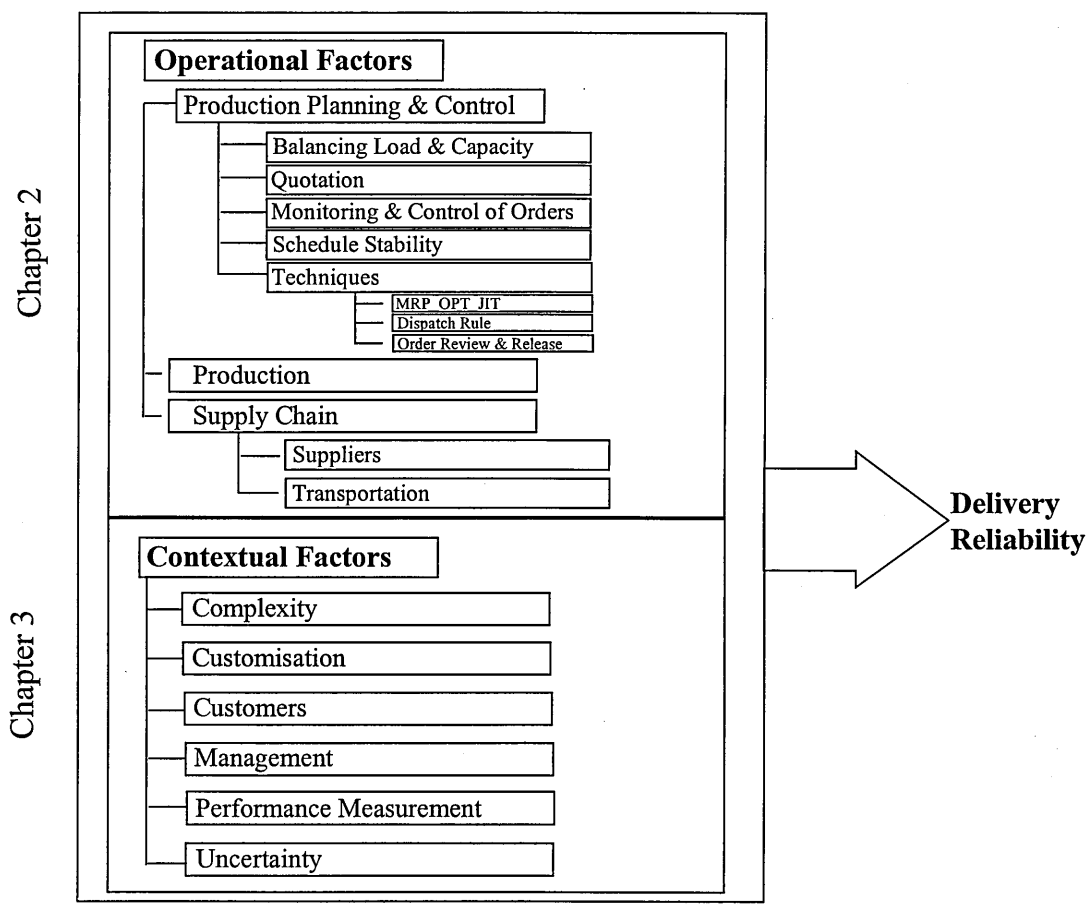

Figure 3.1: The operational and contextual factors that impact delivery reliability.

The chapter starts with an examination of the impact of complexity on delivery reliability. Then the impact of customisation is examined. This is followed by an

examination of the impact of the customer, especially demanding customers is considered. The chapter then covers the influence of plant management, and the performance measurement system. The final area discussed is uncertainty.

3.1 THE PRODUCT - COMPLEXITY

This section will look at the impact of complexity on plant delivery reliability. Complexity is a concern of operations management, according to Hayes, Wheelwright and Clark (1988) because of the impact it has on the control and co-ordination of the production process. Funk (1995) contends that the greater the complexity of a product, the more information is needed to manufacture it. Frizelle & Woodcock (1995) contend that increased complexity has the effect of impeding flow in the factory. They suggest that increased complexity has the effect of extending lead times and making manufacturing operations less predictable. In addition, as Chau and Hamblin (1996) point out complexity may also dampen organisational performance (including delivery reliability).

Chau and Hamblin (1996) contend that the concept of complexity in manufacturing is relatively new, this is certainly the case when compared with such issues as quality. They also feel that there is a slight degree of vagueness in the definition of complexity used by writers. They define the 3 main elements of complexity as follows:

1. Process - number of different processes, number of different process stages
2. Product - number of different end products that are offered, the width of the product range
3. Parts - the number and different types of parts required to produce the various products

Several writers (Stalk & Hout, 1990; Child et al, 1991) claim that complexity impacts organisations costs; as complexity increases so costs rise. However these writers offer

no more than anecdotal evidence to support their assertions. A number of other writers have tried to investigate the impact of complexity on costs. Foster & Gupta (1990) investigated manufacturing overhead cost drivers in an electronics firm. They did not find any significant correlation's between costs and complexity based cost drivers such as total number of parts or breadth of the product line. They concluded that the lack of correlation was due to problems in developing the appropriate measures of complexity for the firm they were studying.

MacDuffie, Sethuraman & Fisher (1996) used data from the International Motor Vehicle Programme study of 70 assembly plants, to investigate the impact of increasing complexity (part and product) on labour productivity and quality. They found that product complexity (distinct model types including body styles and drive train configurations) did not have a negative impact on labour productivity or quality. They attributed the lack of an impact to the fact that the plants were designed to handle a number of model types and body styles. Switching between these different types incurred little penalty, but any style outside the range was essentially unfeasible. However, they did find a significant negative effect of part complexity (engine type, wire harnesses and exterior paint colours) on productivity. MacDuffie et al commented that this was an area where the trend in increasing complexity was most problematic for the manufacturer. This was due to the multiplier effects of choosing to increase the number of exterior colours, wire harnesses or engine transmission combinations.

Cost is not the only area where complexity is considered to have an impact. Complexity may also impact delivery reliability. Wacker & Lucht (1985) contend that an increase in product line complexity makes the predictability of manufacturing lead times poorer. This is due to the increased complexity from more routings, workload variation, increased level of work-in-progress and demand variability. Delivery date quotation becomes more difficult and ultimately delivery reliability may suffer.

Child et al (1991) state that increased product and process complexity means that the factory has to deal with an increase in various elements. Materials management has to purchase and handle several different raw materials, parts and components for the end product as well as several different tools and jigs for the manufacturing process. While, production has to manage the complicated production process with many different raw materials, parts, components, tools and jigs. All this leads to soaring manufacturing costs, rising stocks and low delivery reliability.

While Wacker and Lucht (1985) and Child et al (1991) have proposed that complexity impacts delivery reliability, they offer no research evidence to support their propositions. However, a few researchers have examined the impact of complexity on delivery reliability.

Ritzman, King and Krajewski (1984) using a factory simulation, found that plants that manufactured products with low complexity (fewer levels in the bill of materials) achieved better delivery reliability than those making more complex products. Their research points to the negative influence of complexity on delivery reliability. However, it was based on simulation that, as we have seen in Chapter 2, may not give a true representation of the real world - so their results should be treated with caution. Also they did not examine the impact of the other types of complexity i.e. product or process complexity.

The impact of product complexity on delivery reliability was investigated by Yeh & Chu (1991). Using a survey approach they examined the impact of broadening the product range for three groups of companies - flow shop, continuous and project. The respondents were asked to comment on the possible impact of broadening product lines on delivery reliability. The respondents in the flowshop group of companies reported that broadening product lines had a negative impact on delivery reliability. However, the respondents from the continuous and the project groups reported no significant effect of complexity on delivery reliability. Overall, the respondents felt

that the broadening of product lines meant greater work-in-process inventories, increased scheduling complexity, longer lead times and would also mean more frequent changes in production plans. Yeh & Chu's study indicates that respondents (in the flowshop group) consider broadening the product range would have a negative impact on delivery reliability. However, their results are based on the perceptions of the respondents and so do not provide proof of a direct link between the complexity and the actual level of delivery reliability performance being achieved.

Handfield & Pannesi (1992) found from their survey analysis of US manufacturing plants that the number of products produced by the factory was positively correlated with delivery reliability. They commented that even firms with highly complex product lines could effectively compete on the basis of on-time delivery, despite the problems normally considered to be associated with high product complexity. Their results appear to contradict the views of the other writers examined earlier. However, they excluded service or spare parts manufactured by the plant from their analysis. Therefore, their measure of product complexity was not picking up all the complexity faced by the plant.

Mapes et al (1997) investigated the relationship between product complexity and delivery reliability. They found that there was a negative correlation between product complexity and plant delivery reliability. They concluded that plants that manufacture a wide range of products are likely to perform less well on delivery reliability, than those plants with a narrower range. However, while the relationship is significant, the degree of correlation is, in fact, low (-0.12).

This section has examined the impact of complexity. While a number of writers have proposed that complexity (in its various forms) impacts delivery reliability, only a few studies have examined the relationship between the two variables. A simulation study found that part complexity had a negative impact on delivery reliability. This result should be treated with caution given the fact that the research was simulation based. A

few surveys investigated the impact of product range complexity on delivery reliability, but they do not appear to agree on the impact on delivery reliability. Given the limitations of the research that has been carried out, the impact of complexity on delivery reliability still requires further research.

3.2 CUSTOMISATION

Another important product related factor that influences delivery reliability is customisation. A plant's delivery reliability could be affected by the extent to which it manufactures customised products. Kingsman, Tatsiopoulos and Hendry (1989) make the point that a plant dealing with lots of customised products has a complex situation on its hands. The production planning and control task is more difficult because there is often a high variability with respect to the routing and processing times of all the work. So it is difficult to predict how the work will be distributed among the various work centres in the factory. Since the planning task is difficult, it is likely that the plans produced may result in some customer orders not achieving their delivery date. Dinitz (1990) contends that with customised products it is difficult to estimate the amount of time and capacity to complete each job. Consequently, the delivery date quotation may be unrealistic.

While Dinitz and Kingsman et al suggest that customisation may impact delivery reliability they offer no research evidence to support their views. However, there is some research that illustrates the impact of customisation on delivery reliability. Ritzman, King and Krajewski (1984) using their factory simulation system model found that plants in their simulation who produced a high number of customer specials (customised products) had lower levels of delivery reliability than those plants that did not produce customer specials. However, their research suffers from the drawback of being based only on simulation.

The plant studied by Britchford (1985) produced both customised and standard products. The customised product tended to slow down the throughput rate of the production facilities. He found that the employees gave the standard products preferential attention because they were easier to produce and as a result the customised items tended to be delivered late.

Kochhar and McGarrie (1992) found from their case study research into seven companies, that an increase in the proportion of customised products in the product mix increased the shop floor control and capacity problems. Planning and control is more difficult in an environment where a large proportion of the products were customised. Customised products flowing through a plant will produce fluctuations in the load at work centres. These fluctuations can result in overloading of some of the work centres (and underloading of others). This may result in a loss of capacity and may therefore lead to a decline in delivery reliability.

Various writers have pointed to the detrimental impact that customisation can have on delivery reliability, but there is little research evidence to support these views. Ritzman et al present research evidence to show that there is a direct link between customisation and delivery reliability; delivery reliability is poor when the proportion of customised products being produced is high. The problem with their work is that it is based on simulation. Britchford offers some case study evidence to show that customisation can result in poor delivery reliability. However, the results are based on a single case study and so cannot be generalised to the rest of manufacturing.

So far the literature review has covered the important aspects of the product being purchased (complexity and customisation), but one important element has been ignored. The next section will examine the influence of the person who places the order, that is the customer.

3.3 THE CUSTOMER

The customer may have an impact on plant delivery reliability. Paulden (1977) indicates that the customer may request an unrealistic delivery date, that if accepted by the plant, may result in poor delivery reliability. Any attempt to meet this unrealistic delivery date by the plant may have a knock on effect on other customer orders. Priorities may have to be changed in the factory in order to complete the specific customer order; the knock on effect on other orders may be to delay some of them. Of course the customer can impact delivery reliability at other times as well. As Wemmerlov (1984) points out the customer can impact delivery reliability performance once they have placed an order, by requesting changes to the specification of the product, the order quantity, or the delivery date. Although the plant may be able to accommodate these changes, they may impact the progress of other orders, resulting again in reduced delivery reliability to other customers. While both writers point to the fact that customers impact delivery reliability they offer little research evidence to support their assertions.

The postal survey undertaken by Houseman (1978) of UK Managing Directors found that customers were considered to be the second major factors behind poor delivery reliability (second behind planning and estimating). Customers were considered to cause late delivery, by delaying the despatch of specifications and/or modifying existing orders. However, he does not separate the various factors (placing orders late, etc.) and so we cannot tell which of the factors is the major contributor to delays in delivery. However, he does not separate out the various factors (placing orders etc) and so we cannot tell which of them is the major contributor to delays in delivery.

Fluctuations in the level of customer demand can also have an impact on the manufacturing plant. Uncertainty in demand for the end product can produce MRP nervousness (Blackburn, Kropp & Millen, 1985). The changes in demand lead to order modifications that are propagated through a multi-level system creating

nervousness. As new demands are rolled into the schedule, prior ordering decisions are subject to revision, and when altered can trigger a sequence of order changes throughout the system.

Graham (1986) and Plossl (1988) contend that the uneven demand from customers is one of the major causes of highly variable load being placed on the plant. Highly variable load causes problems for the manufacturing system because it leads to long transient queues developing, especially where the resource is also on average heavily utilised. So while some jobs will pass rapidly from one resource to another, others will have to queue longer at each resource, leading to uncertainty about job completion times. Actual manufacturing lead times will be extended and delivery reliability may suffer.

One area that has received little attention in the academic literature is the impact of "demanding" customers on delivery reliability. Tatsiopoulos and Kingsman (1983) make the observation, that the knowledge that a customer can afford the late delivery of an order can determine the relative value allocated to meeting delivery dates for jobs. It would seem that not all jobs are equal; if a customer is prepared to accept late delivery then this fact may impact the priority his order receives in the manufacturing plant. This also means that if the customer is demanding and will not accept late delivery then the plant manager will put more emphasis on his order when priority decisions need to be made.

Eloranta (1988) points out that Scandinavian bottling plants ship fresh milk on a regular basis with close to 100% delivery reliability. For the customers late delivery means that the time it can sit on their shelves is reduced, which could result in loss of sales. Consequently customers demand high levels of delivery reliability. If the milk is not shipped on-time it will deteriorate and so lose its value. For Eloranta, the key to exceptional delivery reliability is the demands placed on the company by the market. While Eloranta makes a valuable point, it could be argued that the reason that the

bottling plants achieve very high levels of delivery reliability is because they process a simple product (very low part and product complexity) and rather less to do with the influence of the customer.

Malhotra, Jensen and Philipoom (1994) report on a case study of a US metal fabricator that supplied car manufacturers. Some of the contracts with the manufacturers contained clauses that made the supplier liable for cash damages in the event of a late delivery of parts (if the car assembly line was stopped). However, the company did not feel it could profitably fill the shop capacity by supplying only the automotive manufacturers and so it decided to serve other smaller customers. Now while late shipment was to be avoided, these additional customers were considered by the fabricator to tolerate some degree of late delivery. The company decided to aggressively manage the orders to its vital customers, and to fill the remaining capacity with work generated from other customers. Although the same standard lead times were used for all the jobs regardless of customer type, the jobs required by the automotive manufacturers were scheduled immediately upon their arrival into the factory. Normal priority jobs were scheduled around the vitally important customer jobs to insure that the important jobs had the required capacity at the time it was needed. The company used expediting and overtime to provided some slack, if the schedule of the high priority orders fell behind. The extreme penalty clause forced the company to provide close to 100% delivery reliability to its high priority customers -- failure to deliver on time on even a few jobs would have threaten a large contract. The delayed delivery to the non-priority customers, that sometime occurred, was considered an acceptable trade-off.

The influence of demanding customers is not unique to the USA. The UK plant of car seat manufacturer Bertran Faure also supplies demanding customers (Wheatly et al, 1998). The plant's customers do not hold buffer stocks of car seats and so failure to deliver on-time will result in the assembly line stopping. Any failure to delivery on-time by the plant that stops the customer's assembly line results in heavy fine being

levied. The imposition of the fine means that the plant has only been late with its deliveries once, over a three year period.

The writers examined in this section appear to agree that customer can impact delivery reliability significantly. The customer can impact the delivery reliability by for example requesting changes to the specification of the product, or requesting an unrealistic delivery date. There is some survey evidence that points to the fact that the action of customers can result in poor delivery reliability. Writers also point to the impact of fluctuating levels of customer demand on delivery reliability.

An area that has been, in the main, ignored is the impact of "demanding" customers. There is some case study evidence that suggests that demanding customers (in the sense that failure to deliver on-time would result in penalties and possible loss of future business) can cause manufacturing plants to provide them with very high levels of on-time delivery. However, given the small amount of research, this issue still needs further research.

3.4 MANAGEMENT

Several writers point to the importance of management in ensuring high levels of delivery reliability. Paulden (1978), Leonard (1978) and Wooldridge (1978) contends that the responsibility of ensuring delivery on-time is totally one of management. Writers also point to the importance of the various departments having delivery reliability as a mutual goal. Plossl (1973) and Hayes et al (1988) argue that success in the manufacturing operation requires all the managers to have mutual goals. Plossl (1973) contends that lots of companies have department and functions pursuing different goals. For example, the sales managers striving for increased sales volumes without regard for costs and profit, while the manufacturing managers keep costs down regardless of the effects on delivery reliability. Plossl makes the point that too often delivery reliability is held to be the responsibility of only one department —

production planning. For him the managers should have shared responsibilities and should all work together towards common goals, such as delivery reliability. Only in this way, he, feels that success will be achieved.

Both Paulden (1977) and Kingsman, Tatsiopoulos & Hendry (1989) state that management has a role to play in ensuring good delivery reliability. In their view the whole company needs to be focused on delivery reliability. On-time delivery should be the company's main objective; on-time delivery should be the main objective of every department[1]. However, while the various writers state that management has a role in ensuring good delivery reliability they offer no evidence to show just what impact it has on delivery reliability.

New & Sweeney (1984) offer some case study evidence about the influence of management. They found from their study of delivery reliability that the most significant influence on the delivery reliability of a firm was senior management's attitude to the importance of meeting delivery dates. When this was considered to be a key objective of an organisation, a proactive approach to managing manufacturing operations evolved. The plants in their study with good delivery reliability had manufacturing management that was proactive in its approach to meeting delivery promises. However, at the plants with poor delivery reliability the attitude of senior management to the significance of on-time delivery was that it was less important than other issues such as the technical quality and the cost of the product.

A number of writers covered in this section consider that management has a role to play in ensuring good delivery reliability. To achieve good delivery reliability all the departments need to be working together; the whole company should have the shared goal of ensuring on-time delivery. However, the views offered by many of the writers

[1] Neely et al (1994) indicate that the organisational culture literature (Deal & Kennedy, 1982; Ouchi, 1981) suggests that consistency of decision making and action results when the organisations values are shared by all its members - managers and employees. The implication of this view is that if employees and managers consider delivery reliability to be important then their actions and the decisions they take will ensure that on-time delivery is achieved.

are prescriptive in nature. The only research in this area, a case study, suggests that the most significant influence on a firm's delivery reliability is the senior management's' attitude to the importance of meeting delivery data. However, this research was limited to only four case studies and is only for the engineering industry sector. Given the small and limited extent of the research, the issue of the impact of management on delivery reliability still needs to be examined further.

3.5 PERFORMANCE MEASUREMENT

In Chapter Two the issue of the monitoring of delivery reliability was covered, lets now turn to examine the broader issue of performance measurement. Measurement is an important part of the management process, performance measures help the managers to focus on the goals that need to be achieved. They provide the means by which to monitor progress towards the set goals and by comparing monitored performance to planned performance they provide feedback. Neely, Gregory and Platts (1995) suggest the following useful definitions:

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

Performance measurement is an important issue for management. A number of writers suggest performance measures can influence behaviour (Skinner, 1974; Kaplan, 1983; Hopwood, 1984; Mather, 1986; Maskell, 1991; Neely, Mills, Platts, Gregory & Huw, 1994). Individuals are said to modify their behaviour in an attempt to ensure a positive performance outcome, even if this means pursuing inappropriate courses of action (Hopwood, 1984). As Mather (1986) states 'people do what you inspect, not what you expect'. Neely, Mills, Platts, Gregory and Richards (1994) state that performance

measures can be used to influence behaviour and so therefore can affect the implementation of a strategy. They point out that performance measurement is seen in the business strategy literature as an integral part of the strategic control cycle which

- helps managers to identify good performance
- provides a means of introducing individual strategic stretch targets
- ensures that corporate management knows when to intervene because business performance is deteriorating.

They state that in the organisational behaviour literature the link between control and strategy is less explicit, however there is widespread recognition that performance management systems can be used to focus activity. They comment on the operations management literature that while that the focus tends to be more uni-dimensional, performance measurement is seen as a primary means of inducing consistency of decision making and action.

If performance measures can influence behaviour then the design of the performance measurement system should be treated with care (Dixon, Nanni & Vollmann, 1990; Neely, Richards, Mills, Platt and Bourne, 1997)[2]. Lockamy (1994) in his paper about creating a delivery reliability measurement system, contends that a performance measurement system must contain mechanisms for ensuring consistent actions on shared objectives between organisational levels and across functional areas. He feels that the manufacturing company must ensure that the performance measurement system used at the various levels and functions of the firm are focused on achieving the strategic objectives. Mechanisms are required which provide horizontal and vertical linkages between the various systems. These linkages promote organisational focus whereby the actions and behaviours in the firm concentrate on achieving the strategic objectives, making consistent decisions and supporting those activities necessary for accomplishing strategic objectives.

[2] Dixon, Nanni & Vollmann (1990) recommend the use of their Performance Measurement Questionnaire to assess the status of a manufacturing company's measurement system. The questionnaire can be used to determine if there is a match between the firm's strategies, actions and

Neely and Wilson (1992) point to the importance of an organisation having goal congruence. They define goal congruence as the extent to which the relative importance of the key performance criteria of the organisation are understood. If there is a high level of goal congruence in an organisation then everyone agrees about the relative importance of the key performance criteria. Neely and Wilson suggest that a common understanding of these criteria by the managers will enable members of the organisation to make supportive decisions and discourage dysfunctional actions taking place.

A number of research studies point to the impact that the performance measurement system can have in the manufacturing operation. The first real major study in the operations management field was carried out by Richardson and Gordon (1980), who investigated manufacturing performance measures and their effect on the organisation. They investigated fifteen manufacturing organisation in South Eastern Canada, and looked at the issue of performance measures from the perspective of the product life cycle. During the life cycle the critical tasks for manufacturing change, so they proposed that different performance measures would be used at each stage of the life cycle. They found that the performance measures used did not change as the products progressed through the various stages. Also, the measures the companies used were suitable for the maturity stage of the product life cycle, even though the various plants investigated had products that were at various stages of the product life cycle. Richardson and Gordon found that managers responded to perceived measures of their performance. If these measures were not in line with corporate strategy then this strategy would become ineffective in the long run. They found that the measures had a detrimental impact on performance, in particular they had inhibited innovation.

The research carried out by Richardson and Gordon shows that the performance measurement system can have a detrimental impact on company performance.

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measures. While Neely et al (1997) suggest a framework - the performance measure record sheet -

Research described by Fry and Cox (1989) shows the specific effects that the performance measurement system can have within the manufacturing plant. Fry and Cox interviewed various levels of managers and workers in a US plant to identify the action each took to improve their performance measures. They found that the plant manager was primarily concerned with return on investment. The product group managers (whom all reported to the plant manager) were evaluated on due date performance (order shipped on time). The shop floor supervisors and machine operators were evaluated on the basis of the standard efficiency measures of units produced per standard.

Fry and Cox found that the different performance measures used resulted in different forms of action. The workers were caught in the performance trap; they would often produce larger than scheduled batches, if a particular operation was running smoothly ahead of standard, extra units would be produced. These units would not be included in the day's production report but hidden away and they would be reported at a later date when the schedule again called for the production of that particular part. They also produced jobs out of sequence, the ones that were easy to produce and beat the standard were often chosen ahead of the more difficult ones. Through the use of these methods they were able to maintain acceptable levels of efficiency. However, the negative effects of the actions taken by the operators and supervisors to maintain efficiency caused the due-date performance to suffer. So the product group managers were therefore forced to schedule Saturday work and overtime in order to try to reduce the unfavourable delivery reliability level. However, these actions did not help the plant manager. The frequent use of overtime caused the investment in labour to be unnecessarily high, thus the return on investment (ROI) was adversely affected. Fry and Cox contend that the performance measures used at the plant were inconsistent. The improvement in one performance criterion actually worsened the local performance of the higher level management. However, this was not the initial intention of the various measures used in the plant, after all, the concept of labour

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which can be used to design and audit performance measures.

efficiency was supposedly in tune with ROI. Their research shows that the optimisation of performance by one department can have a negative knock on effect on other departments if the performance measurement system has internal inconsistencies.

Harrison, Holloway and Patell (1990) investigated the performance measures used at a US semiconductor plant, and they found that the measures used had an impact on the actions taken by the employees. The production planners were measured on the reliability of their promised delivery dates being achieved. This caused them to provide delivery date quotations that were conservative. While the manufacturing department would supply the planners with data about the manufacturing lead times which also tended to be conservative. They did this because they wanted to be able to manage the release of the orders[3] in the factory in order to be able to maintain productivity (which they were monitored on). Harrison et al commented that this 'satisfying' ultimately meant that the management would never find out just how short manufacturing lead times could be or how much capacity really existed.

Blenkinsop and Burns (1992) examined the consequences of a change in a factory performance measurement system. The case study company adopted a new performance measurement system that consisted of several non-financial (i.e. delivery reliability) as well as financial measures. However, the company failed to introduce the organisational changes that were needed to accompany the new system. The end result was that there was no obvious shift away from the dominance of financial performance measures. It did not take long before the shop floor employees realised that the real measures were still those which concerned sales value and so they changed their behaviour and concentrated on the financial measures. Blenkinsop and Burns identified the fact that the employees sought to maximise their own performance within the framework of their performance measurement system. So, if

[3] Manufacturing had the ultimate control of which day to release the order, planning only specified the month.

the framework was financially orientated the employees became financially orientated too.

Neely et al (1994) investigated the hypothesis that managers of small and medium sized UK manufacturing firms would attribute greatest importance to those performance measures that most closely matched their firms manufacturing task. The results of their survey (344 responses) pointed to the fact that their hypothesis could be accepted. The managers surveyed did attribute the greatest importance to these performance measures that most closely matched their firms manufacturing task (the performance measures were congruent with the firms competitive stance). They found that the hypothesis held for the various competitive stances a firm could adopt except price. The firms that competed on price tended to perceive delivery on time as their most important performance measure (rather than cost versus budget or unit product costs). They offered various suggestions for this result but suggested further research was required before these could be confirmed or refuted. However, their research did not indicate if there was any difference in the performance of those firms whose performance measures were congruent with their competitive stance and those where there was no congruence.

While the various research studies examined so far have pointed to the impact of performance measures, none has explicitly covered delivery reliability. This is an area covered by the research of New and Sweeney (1984). They found from their four case studies of manufacturing delivery reliability that plants with poor delivery reliability had performance measurement systems that were orientated towards ensuring high levels of facilities utilisation. Consequently the emphasis of management was placed more on minimising cost rather than meeting promised delivery dates. This focus was found to be less pronounced at the plants with high levels of delivery reliability. However, their research consisted of four case study plants in one industry sector and so only tentative conclusions should be drawn from it.

This section has examined the influence of performance measures. Several writers contend that performance measures influence employee behaviour but the research backing up these assertions is not extensive. What evidence there is, suggests that employees are influenced by performance measures. The research also indicates that the performance measurement system can have a detrimental impact on company performance. Employees will try to improve performance on those performance measures they are measured on (or perceived they are measured on) even if this activity is not in line with the ultimate company goals. There is also some case study research to show that the performance measurement system was impacting delivery reliability performance. However, given the low level of research the issue of the impact of the performance measurement system on delivery reliability still need further investigation.

3.6 UNCERTAINTY

Uncertainty is a concept that received attention in the Organisational Behaviour literature in the 60s and 70s, in particular with relation to uncertainty in the environment. Emery and Trist (1965) were early researchers of this theme. They suggested the concept of turbulence and its opposite, placidity. Turbulence is a measure of the change that occurs in the factors or components of an organisations environment. The amount of environmental turbulence is closely related to the degree of uncertainty facing a firm. As the environment becomes increasingly turbulent, factors become less predictable and more uncertain; the values of important variables and the variables themselves move in an erratic fashion. Aldrich (1979) suggests that uncertainty impacts the ability of the organisations participants to make decisions.

Lawrence and Lorsch (1969) identified that environmental uncertainty is made up of three elements: i) lack of clarity of information, ii) general uncertainty of causal relationships between decisions and the correspondent results iii) and elapsed time between a decision and feedback about the results. Duncan (1972) criticised Lawrence

and Lorsch's definition of uncertainty, but he adopted one that was similar in two of the three elements: i) lack if information ii) unknown degree of lose due to an incorrect decision and iii) the inability to assign probabilities to the effect of environmental factors on the organisation. The definitions presented by these writers points to the importance of information to help predict future events or trends. Galbraith (1973) points to the importance of information processing. As he states the greater the uncertainty of the task, the greater the amount of information that has to be processed by the decision makers. In Galbraith's view an organisation can adopt various strategies to deal with problems of uncertainty. First it can attempt to increase its ability to pre-plan, by better co-ordination of different tasks or functions. Secondly it could try to increase its flexibility to adapt to its inability to pre-plan, possibly by loading resources well below their capacity limits. Finally it could take action that could decrease the level of performance required for its continued viability.

Lenz (1980) points to the fact that the external environment is a source of events and changing trends that create opportunities and threats for individual firms. In his view the level of environmental uncertainty that a manufacturing company experiences can have a dramatic influence on the company performance.

The manufacturing literature suggests that uncertainty presents a problem for managers of manufacturing plants. Hayes, Wheelwright, and Clark (1988) contend that uncertainty adds to the complexity of running a factory. While others point to the difficulty of managing in an unpredictable environment (Puttick, 1987; Davis, 1993). In broad terms the literature indicates that uncertainty can be classifies into two groups, external and internal (Gerwin, 1986; Graham, 1986; Puttick, 1987; Hayes, Wheelwright, & Clark, 1988; Newman, Hanna, & Maffei, 1993). External uncertainty relates to the environment the company operates in e.g. customer demand uncertainty, uncertainty in supplier delivery, the uncertainty of the actions of the competitors. Internal uncertainty is concerned with the behaviour of the people and equipment within the plant four walls e.g. uncertainty of the equipment availability.

A number of writers suggest that uncertainty is one of the factors that drives an organisation to seek flexibility (Gerwin, 1986; Swamidass & Newell, 1987, Gupta & Goyal, 1989; Slack, 1989; Newman, Hanna, & Maffei, 1993). Slack and Gerwin outline different types of flexibility that an organisation can develop to deal with uncertainty (the reader is recommended to consult their work for further information).

Uncertainty is said to have an impact on the design of the production planning system. Van Dierdonck & Miller (1980) use the concept of uncertainty as part of their contingency model designed to explain aggregate differences in the specifications of production planning and control systems across firms. They state that the production planning task is characterised by three main descriptors in their model; complexity, uncertainty and the toleration for slack. These three factors impact the type of approach to planning and control systems that a company should take. For them uncertainty describes the reliability of the information and the assumptions that are used in planning and controlling production. They suggest that there are four sources of uncertainty: demand uncertainty[4], supply uncertainty, goal uncertainty and production uncertainty[5].

Puttick (1987) developed a complexity/uncertainty matrix (see Figure 3.2) as a tool for planning the use of advanced product technology, process technology and systems so as to achieve a significant advantage in performance in the market place. For Puttick the concept of complexity is a function of the product and what it takes to make it. In the case of uncertainty it is made up of two elements -- external and internal. The external problems derive from the market place and the unpredictability of the customers who do not place their orders for the volumes or variety of products or at the time that the company forecast. While the internal problems stem from the

[4] Demand uncertainty for an organisation can be measured by the extent to which future demand can be predicted.

[5] Production uncertainty is a function of the reliability and stability of products, people, specifications and processes.

unreliability of the machines and processes, the absenteeism of people and the many other things that can go wrong inside the plant.

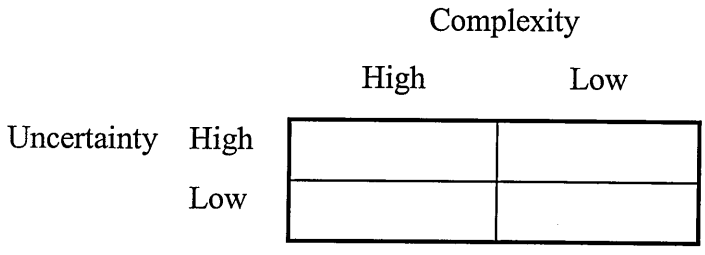

Figure 3.2: Complexity/uncertainty matrix (Puttick, 1987).

His matrix, he claims, can be used to indicate the critical competence that the manufacturing company needs to process. Each quadrant of the matrix also indicates the overall emphasis that needs to be placed on technologies, equipment or systems. However, one of the deficiencies of the model is that he does not provide any instrument with which to measure the two concepts of complexity and uncertainty, we can only make informed judgements using his descriptions.

Bhattacharya, Jina and Walton (1996) draw a distinction between the concept of uncertainty and variability. For them variability measures the changes in demand on a manufacturing system over a given sequence of time buckets, forecast at a given point in time. While uncertainty measures the changes in demand on a given time bucket as it moves in time and approaches the delivery due date. The effects of variability and uncertainty, they argue, are to increase the turbulence in a manufacturing system. In their view, manufacturing turbulence inhibits the smooth flow of material through the whole pipeline. It is important to understand that it is not the variation of the future events that matters rather the sudden deviation from the expected movement that is important with regard to uncertainty. If the movement is away from the expected then it is uncertain. However, if the change in events is dramatic but expected then we are dealing with variability and not uncertainty.

Swamidass and Newell (1987) state that uncertainty has received little attention in the manufacturing literature. They carried out a study into the impact of environmental uncertainty on manufacturing strategy content and process, and manufacturing strategy's influence on business performance. Their measure of uncertainty[6] consisted of six elements which respondents had to rate on a scale of one to five (ranging from always predictable to never predictable). The six elements (mainly external) were: actual users of your product; competitors for your supply of raw material and parts; competitors for your customers; government regulations controlling your industry; public's political news and attitudes towards your industry and your relationship with trade unions. They also examined the impact of flexibility (using a composite measure of flexibility). The sample they used in the research was small (only 35 plants), but the results were interesting. They found that the role of manufacturing managers in strategic decision making was a function of environmental uncertainty. The higher the level of uncertainty, the greater the tendency to reduce the role of the manufacturing management in strategic decision making. They also discovered that the higher the role of manufacturing managers the better the performance of the plant. Swamidass and Newell found that the greater the flexibility, the better the performance (performance was measured using sales growth) of the plant. The prescriptive conclusion they came to was that an organisation may find at least some help in coping with high uncertainties imposed by the environment by increasing manufacturing flexibility and by maintaining or at least ensuring that there was a role for manufacturing management in strategic decision making.

Ho (1996) investigated the relationship between environmental uncertainty[7], risk, manufacturing strategy and performance. His research was focused on three industry sectors: electronic parts, personal computers and machine tools. He found that the role

[6] Swamidass & Newell used perceptual measures of uncertainty. A set of stimuli lack meaning or information value until they are perceived by an individual. Perception refers to the process by which individuals organise and evaluate the stimuli (Secard & Backman, 1964). Swamidass & Newell agree with other researchers (Downey & Sloan, 1975) that only through managerial perception does environmental uncertainty become known to the organisation.

[7] Environmental uncertainty covers all the physical and social factors outside an organisations boundaries. It includes customers, suppliers, competitors, government, unions and technology.

of manufacturing and manufacturing planning activities had a negative correlation with uncertainty. In times of high uncertainty, other considerations supersede the manufacturing functions and its strategic role is reduced. The high uncertainty makes it difficult for the manufacturing planning system to function properly. Ho found that uncertainty had a considerable negative impact on the firm's profits. The research also found that flexibility, and environmental interaction (having information about the external environment) were important management instruments in dealing with uncertainty. While Ho's results are interesting, they are based on a small sample (25 companies) taken from only three industry sectors.

Uncertainty is recognised by many writers to have an impact on the manufacturing system. However, the writers have not researched the impact of the various components of uncertainty, in particular the impact of one component demand uncertainty. There does not appear to be any research examining the impact of uncertainty, or one of its main components demand uncertainty, on plant delivery reliability.

3.7 CONCLUSION - CHAPTER 2 AND 3

The literature relating to delivery reliability has been examined in Chapters Two and Three, in the former the operational factors were covered and in the later the contextual factors. The review suggests that there are a number of gaps, areas where further research needs to be undertaken. Let us take each of the major areas examined in Chapters Two and Three, and examine where further research is necessary; Table 3.1 indicates the areas where the gaps exist.

3.7.1 Production Planning and Control

The literature points to the importance of production planning and control in ensuring high levels of delivery reliability. Most of the literature tends to concentrate on the

impact of the various techniques, one of the issues examined is the impact on delivery performance. There is a fair amount of literature covering this factor.

3.7.2 Balancing Load and Capacity

The literature indicates that making sure load and capacity balance, is important in ensuring good delivery reliability. There is some simulation research to indicate the importance of carrying out this activity. This activity was considered to be a subset of production planning and control and was therefore examined during the research.

3.7.3 Quotation

The literature points to the importance of arriving at an achievable quoted delivery date. The review of the literature indicates that there was a difference between manufacturing companies in terms of which function (production planning, sales) was responsible for determining the delivery date quotation. However, there was no research evidence to suggest if this difference in the function made any difference to the delivery reliability of the plant. This is a gap in the research that warrented futher investigation.

3.7.4 Monitoring

The literature points to the importance of monitoring delivery reliability and the progress of orders in order to ensure that high levels of delivery reliability are achieved. There is some survey evidence to indicate that plants that monitor their delivery reliability outperform those who do not. In addition, there is some case study evidence to indicate that poor delivery reliability is to some extent due to the poor monitoring of orders. Overall, however, monitoring and its impact on delivery reliability has been poorly researched.

Area	Section	Issue	Notes on research	Conclusion	Investigated
Production Planning and Control	2.1 & 2.1.5	The approach has a key role in ensuring high levels of delivery reliability	The research concentrates on the impact of various techniques	This was considered to be one of the internal factors -see model in Chapter Four	Y
Balance Load and Capacity	2.1.1	If load exceeds capacity delivery reliability will decline	Simulation based research	Important element of quotation and planning and control	Y
Quotation	2.2.2	Influence of the functions on delivery reliability	No direct link proven	Gap exists needs further investigation	Y
Monitoring	2.1.3	Poor monitoring associated with poor delivery reliability	Limited - some survey and case study evidence	Gap exists needs further investigation	Y
Schedule Stability	2.1.4	Stable schedule leads to high levels of delivery reliability	Limited - simulation evidence	Gap exists needs further investigation	Y
Production	2.2	Delays in production will impact delivery reliability	Limited - some case study and survey evidence	Gap exists but likely to be of low influence on delivery reliability	Y
Supply Chain Management	2.3	The approach is considered to lead to improved delivery performance	Limited - some survey evidence	Gap exists but the research area is extensive and outside main area of interest which is the factors that impact plants own delivery reliability	N
Suppliers	2.3.1	Poor supplier delivery reliability is associated with poor plant delivery reliability	Limited - some case study evidence	Gap exists needs further investigation	Y
Transportation	2.3.2	Poor transport management will result in late delivery	Limited evidence, mainly anecdotal	Gap exists but issue is outside main area of interest, looked at the delivery reliability of suppliers	N
Complexity	3.1	Complexity impacts plant delivery reliability	Limited - some survey and simulation evidence.	Gap exists needs further investigation	Y
Customisation	3.2	Customisation impact delivery reliability	Limited - simulation & cases study research	Gap exists needs further investigation	Y
Customers	3.3	Demanding customers impact delivery reliability	Very limited - case study	Gap exists needs further investigation	Y
Management	3.4	High delivery reliability derives from the whole management team focused on delivery reliability	Very limited - case study	Gap exists needs further investigation	Y
Performance Measurement	3.5	The performance measurement system can impact delivery reliability	Very limited - case study	Gap exists needs further investigation	Y
Uncertainty	3.6	Impact of demand uncertainty on plant delivery reliability	None	Gap exists needs further investigation	Y

Table 3.1: Research areas and the possible gaps.

3.7.5 Schedule Stability

The literature suggests that poor schedule stability can result in poor delivery reliability. However there is little evidence to support this assertion and so a gap exists which needs further investigation.

3.7.6 Production

The literature suggests that delays in production may impact delivery reliability. There is case study and simulation evidence to support this assertion. This area needs further investigation.

3.7.7 Supply Chain Management

The literature suggests that delivery reliability can be improved through the adoption of supply chain management. However, there is very little empirical evidence to support the assertions made in the literature. A gap exists but the issue is outside the main area of interest, which is concerned with the main factors that influence plant delivery reliability. Therefore, the whole area was outside the scope of this research.

3.7.8 Suppliers

The literature suggests that late delivery by suppliers can lead to poor delivery reliability. However, the research evidence to support the assertions made in the literature is limited. The only research evidence available consisted of a limited number of case studies. Given the limited amount of empirical research there is a gap in the evidence available to support a connection between supplier delivery reliability and plant delivery reliability.

3.7.9 Transportation

The literature suggests that poor transport management will result in poor delivery reliability. However, there is very little empirical evidence to support the assertions made in the literature. A gap exists, but the issue is outside the main area of interest which is the main factors that influence plant delivery reliability. Therefore the whole area was outside the scope of this research.

3.7.10 Complexity

Complexity is considered by several writers to have an impact on plant delivery reliability. However, while a number of writers have proposed that complexity (in its various forms) impacts delivery reliability only a few have researched the relationship between the two variables. There has been some limited survey research into the impact of product complexity on delivery reliability. However, in the case of part complexity the only research carried out involved the use of simulations. No survey research exists to indicate the impact of part complexity on delivery reliability. The limited extent of the research represents a gap that needs to be filled.

3.7.11 Customisation

Another factor that may have an impact on delivery reliability is customisation. The literature suggest that increased customisation results in poor delivery reliability. However, the research evidence is limited, only simulation and case study. The limited extent of the research is an important gap in the research that needs to be filled.

3.7.12 Customers

The literature indicates that the customer can have an impact on a plants delivery reliability. A few writers suggest that demanding customers impact delivery reliability in a positive way; demanding customers may produce high levels of delivery reliability. However, the evidence that supports this view is very sparse, only one case study. The fact that there is very little research into the relationship between demanding customers and delivery reliability indicates a gap that needs to closed.

3.7.13 Management

The literature indicates that management has a role to play in ensuring good delivery reliability. In particular that the achieving good delivery reliability requires the whole management team working together to ensure that customer delivery dates are met. There is only one piece of case study research that indicates that plants with high levels of delivery reliability have a management team focused on meeting delivery dates. Given the sparse amount of research, this issue needs further investigation.

3.7.14 Performance Measurement

The performance measurement system is considered by some to influence employee behaviour - employees are said to try to improve performance on those measures they are measured on. There is some case study evidence that points to the fact that plants with poor delivery reliability have reliability measurement systems orientated towards cost measures, but again this area needs further investigation.

3.7.15 Uncertainty

Uncertainty is another area that needs to be investigated. Many writers recognise that it has an impact on the manufacturing system; however little research has been carried out to determine what impact demand uncertainty has on delivery reliability.

Chapters Two and Three have examined the literature relating to delivery reliability, let us now move onto Chapter Four that will outline the research questions that arose from the literature review.

CHAPTER FOUR

THE RESEARCH FOCUS: RESEARCH QUESTIONS, HYPOTHESES AND DESIGN

4.0 INTRODUCTION

This chapter presents the research questions and hypotheses and it also outlines the research design. The first section outlines the research questions were derived from the literature, and outlines a conceptual model of the major factors which impact plant delivery reliability. The chapter then moves on to cover the research hypotheses and propositions (in section 4.2) that arose from the initial research questions. The seven step research process that was adopted to carry out the research is then discussed (in section 4.3). The next section (section 4.5) outlines the scope of the research; which concentrated on delivery reliability at the plant level rather than at the company level. The final part of the chapter outlines the research design used.

4.1 RESEARCH AREAS

The literature review presented in the last two chapters highlights the fact that the pool of empirical research specifically on the subject of delivery reliability is small compared to the volume of research carried out into the issue of, for example quality. This position needs to be rectified given the fact that delivery reliability is an important strategic variable.

The literature review and visits to several manufacturing plants led the researcher to develop an initial exploratory research question: "What plant related variables impact delivery reliability?" This research question was too broad and so it was decided to define a number of more specific research questions that flows from it.

In order to help focus the research a conceptual model (see Figure 3.1) of the major

factors that impact plant delivery reliability was developed, based on the Operations Management literature relating to delivery reliability (outlined in Chapters Two 2 and Three). Table 3.1 (Chapter Three) highlighted the various variables that had an impact on plant delivery reliability. Customisation, part complexity, demanding customers, supplier delivery reliability and demand uncertainty were all considered to impact delivery reliability. The quotation of feasible delivery dates along with the planning and progress control of materials and manufacturing were considered to have a role to play. The management focus and performance measurement system focus were also considered to have an impact on plant delivery reliability. Given the scope of the research project was the plants, the issue of supply chain management and transportation were considered to fall outside the field of investigation.

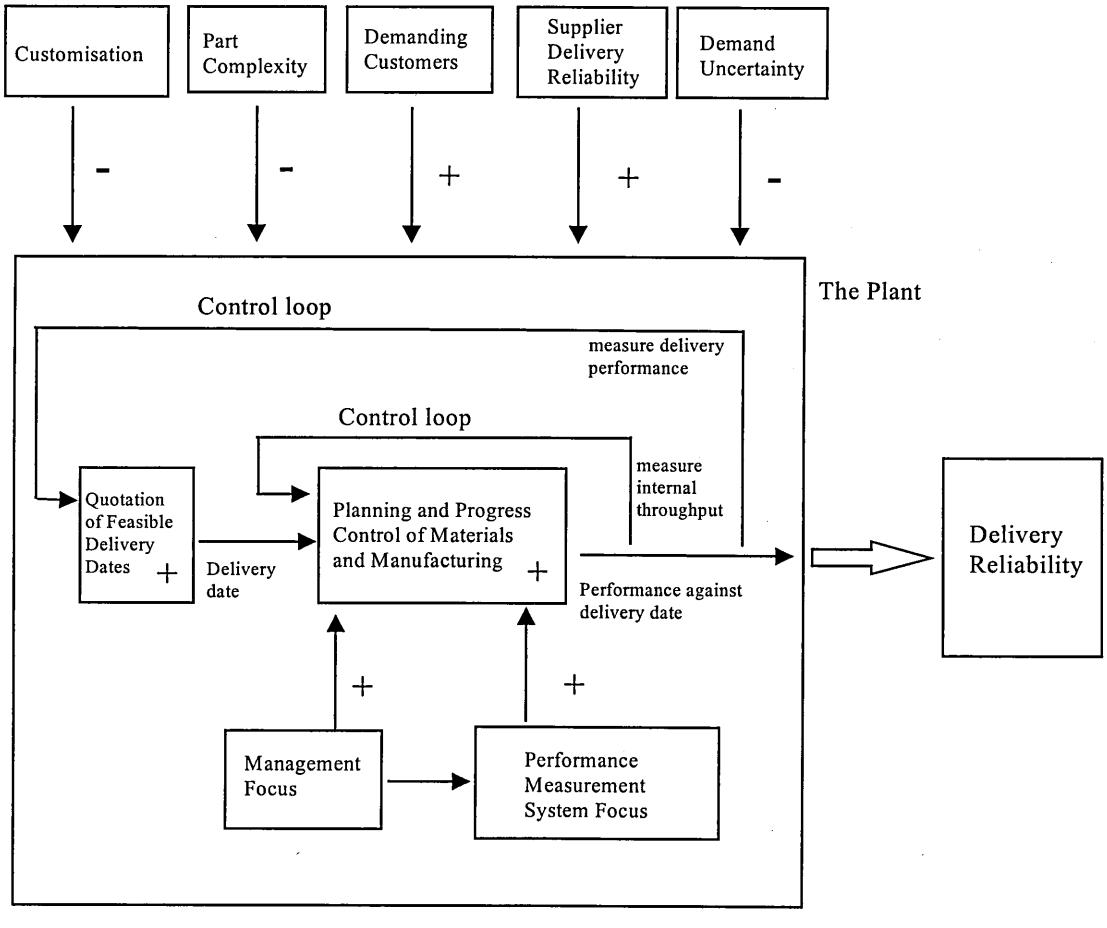

Figure 4.1: Conceptual model of delivery reliability.

The model shows the major factors that impact plant delivery reliability, and the relationship between each factor and delivery reliability. If we look at the top of the

model we can see that it proposes that there is a negative relationship between part complexity and delivery reliability. The model suggests that as part complexity rises so the level of plant delivery reliability declines. The literature reviewed in Chapter Three indicates that part complexity and its relationship with delivery reliability has not been researched in depth. The literature examined suggests that part complexity may possibly have an impact on plant delivery. Ritzman et al (1984) simulation suggests that plants having to deal with less complex products achieved better delivery reliability than those that had to deal with more complex products. However, their findings were based on simulation, which is only relevant to the given situation being examined and not outside the parameters set. The research carried out, in the past, gave rise to the following research question:

Q1 What is the relationship between the part complexity experienced by the manufacturing plant and delivery reliability?

Another area that has received little attention is the impact of customisation. The model suggests that there is a negative relationship between customisation and delivery reliability. It suggests that as the proportion of customised products produced by the plant (as a proportion of its output) increases so the delivery reliability declines. A plant manufacturing a large number of customised products has to deal with a complex situation. As Kingsman et al (1989) point out, the production planning and control task are difficult because there is often a high variability with respect to the routing and processing times of all the work. This means that it is difficult to predict how the work will be distributed among the various work centres in the factory at any point in time. Since the planning task is so difficult it is likely that the plans produced may result in some customer orders not achieving their delivery date. Ritzman et al (1984) using simulations found that plants supplying only standard products achieved better delivery reliability than those plants that supplied some customised products. Their findings suffer from the problem of being simulation based. The issue of customisation gave rise to the second research question. The research question was:

Q2 Are there differences in delivery reliability between those plants that make a large proportion of customised products and those that only make standard products?

The model in Figure 4.1 proposes that there is a positive relationship between demanding customers and delivery reliability; more demanding customers will enjoy high levels of delivery reliability. One of the few studies in this area was by Malhotra, Jensen and Philipoom (1994) who found that the demanding customers supplied by the case study plant enjoyed nearly 100% on-time delivery. The less demanding customers received a lower level of on-time delivery. Do the tough customers drive the plant to provide high levels of delivery reliability? It may be that the plants who serve demanding customers have the same level of delivery reliability as those plants that supply less demanding customers. The third research question was therefore:

Q3 Are there differences in delivery reliability between those plants that have demanding customers and those that do not have demanding customers?

The conceptual model also indicates that the delivery quotation process is important to delivery reliability. As a number of the writers (Paulden, 1977; New and Sweeney, 1984; Kingsman, Tatsiopoulos and Hendry, 1989; Hatoum & Chang, 1997) point out, one of the most important activities involved in ensuring good delivery reliability is the process of delivery date quotation. If the delivery date quotation is unrealistic then this means that the order will not achieve its quoted due date. One of the departments involved in determining the delivery date quotation is the production planning department, however there are also other departments involved (New & Sweeney, 1984). Do plants where the planning department is involved in the delivery date quotation achieve better delivery reliability than those where another department such as sales are involved? This issue gave rise to the fourth research question:

Q4 Are there differences in delivery reliability between those plants where the production planning department is responsible for providing the delivery quotation and those where another department provides the quotation?

The model suggests that there is a relationship between the focus of the management team on delivery reliability and plant delivery reliability. The research carried out by New and Sweeney (1984) found that in plants with high levels of delivery reliability the management was proactive in its' approach to meeting delivery promises. The management orientation was towards meeting customer delivery promises. However, the authors found that in the plants with poor delivery reliability the senior management attitude towards delivery reliability was secondary, the technical quality and the cost of the product were far more important. The fifth research question was:

Q5 Are there differences in delivery reliability between those plants that have a management team focused on delivery reliability and those where the management team lack that focus?

Allied to the issue of the focus of the management team is the focus of the performance measurement system used in the factory. The model suggests that the focus of the performance management system on delivery reliability is related to delivery reliability. The research carried out by Richardson & Gordon (1980) and Fry & Cox (1989) showed that managers responded to those performance measures that they perceived were as measures of their performance. New and Sweeney (1984) found that plants with poor delivery reliability had performance measurement systems focused on facilities' utilisation. Consequently a much greater emphasis on minimising costs rather than meeting promised delivery dates. The research studies gave rise to the sixth research question:

Q6 Are there differences in delivery reliability between those plants that have a performance measurement system focused on delivery reliability and those plants where the focus is missing?

The model also indicates that a number of other variables may have an impact on delivery reliability. One variable shown in the model is supplier delivery reliability. Case study research carried out by Cunningham & Dale (1983) and Britchford (1986)

points to the impact of late delivery by suppliers has on a plant's delivery reliability. In the model, supplier delivery reliability is positively related to delivery reliability, as the supplier delivery reliability improves so the delivery reliability also improves.

The literature suggests that demand uncertainty can have a detrimental impact on the manufacturing plant. The model suggests that demand uncertainty is negatively related to the level of delivery reliability. As the level of uncertainty increases so the level of plant delivery reliability falls.

The centre of the model contains two elements that have been based on an existing model of delivery reliability (The Total Delivery Management Concept) developed by New and Sweeney (1984). They and a number of other writers (e.g. Paulden, 1977; Kingsman, Tatsiopoulos and Hendry, 1989) point to the importance of quoting feasible delivery dates. If the delivery date quotation is unrealistic then this means that the order will not be produced by the quoted due date. Therefore the model indicates a positive relationship between the quotation of feasible delivery dates and plant delivery reliability. The second component that comes from New and Sweeney concerns the planning and progress control of manufacturing and materials. A number of other writers (Goddard, 1986; Plossl & Wright, 1973) have pointed to the importance of planning and control in the factory. Planning is only part of the second element as several writers (Paulden, 1977; Nicholson, 1982) have shown. Once the plans have been released into the shop floor it is important to monitor their progress and take corrective action when they begin to fall behind. The relationship between planning and progress control and delivery reliability is positive. If effective planning and progress control are taking place then the delivery reliability will be good.

4.2 RESEARCH HYPOTHESES AND PROPOSITIONS

The previous section outlined the research questions that arose from the literature, these questions gave rise to two hypotheses and four propositions. The research questions relating to complexity and customisation gave rise to the following two

research hypotheses:

H1. Plants that manufacture a low proportion of their output as customised products are likely to have a higher level of delivery reliability than those plants that manufacture a high proportion of their output as customised products.

H2. Plants that manufacture relatively complex products are likely to have lower levels of delivery reliability than plants that manufacture relatively simple products.

The remaining four research questions were examined via the use of a more exploratory approach. Consequently, the following four propositions were developed:

P1. In plants where the production planning department determines the delivery quotation, the level of delivery reliability will be high.

P2. In plants where the customers have expectations of high levels of delivery reliability, the level of delivery reliability will be high.

P3. In plants where the management team is predominantly focused on delivery reliability, the level of delivery reliability will be high.

P4. In plants where the performance measurement system has delivery reliability as a key area of focus, levels of delivery reliability will be high.

4.3 RESEARCH PROCESS

The research process involves a series of steps, these are outlined in Figure 4.2 (Neuman, 1997). The process is similar to the approach outlined by Flynn et al (1990) and other researchers (Alreck and Settle, 1985). The process starts with the researcher selecting a topic - a general area of study or issue. This "topic" is usually far too broad for conducting specific research and so the next step is crucial.

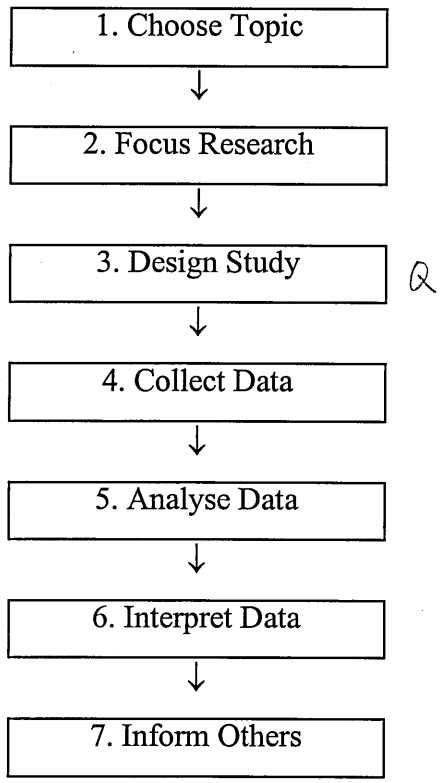

Figure 4.2: The 7 steps in the research process (based on Neuman 1997).

The researcher then narrows down or focuses the research into a specific research question or questions that he can address in the study. During this stage the researcher may develop a possible answer or hypothesis. Having specified the research question (and the hypotheses that may go with it) he will carry out the specific study. The third step involves making decisions about the research design for example whether to use a survey or case study. The third stage also involves the practicalities of the research design adopted, for example the questionnaire design.

Once the researcher has collected the data (step four), the next step is to manipulate and analyse the data to see if any patterns emerge. The patterns in the data help the researcher to interpret or give meaning to the data. The final step of the process involves informing others about the results of the research. The last step can involve the production of a report, the issuing of a press release, the submission of a journal article or as in this case a dissertation.

The neat seven step process shown in Figure 4.2 is, of course somewhat, oversimplified. Research is an interactive process in which the steps blend into each other. A later step may cause reconsideration of a previous one. The process is not linear, it may flow in several directions before reaching the end. Also the process is ongoing; the end of one study often stimulates new ideas and fresh research questions - and so the process moves on in a circular motion.

The research presented in this thesis follows the general principle of the seven step process[1]. The only difference is that this document is only a small part in the process of informing others (step seven).

4.4 TRADITIONAL APPROACH TO RESEARCH

Operations management (OM) research was in its early years dominated by modelling and simulation, especially in such areas as inventory control and scheduling. The operational research/management science approach tended to dominate. Chase (1980) in his study of four OM journals (for the period 1977 to 1979) found that the research tended to be narrow in focus, dominated by the application of techniques for scheduling and inventory control. Gupta (1971) makes the valuable comment about this literature, that the theoretical solutions of scheduling problems that were so prominent in the literature are actually of no appreciable use to practising schedulers. Filipini (1997) points to the fact that during between the 50s and the 70s the emphasis of Operations Management research was very descriptive in its approach. The emphasis was on techniques: time and motion study, plant layout, production control and descriptions of how production systems work.

Meredith et al (1989) found that this focus on scheduling and inventory in the published research literature had changed little in the late 80s, although the area of manufacturing strategy had attracted more attention than in the previous period. Swamidass (1991) analysed the paper published in eight relevant Operations

[1] Taking the key stages outlined in Figure 1.3, stages 1 to 2 equate to steps 1 to 2 in Figure 4.2. While stages 3 to 5 equate to steps 3 to 6 in Figure 4.2.

Management journals (during the 80s) and concluded that in the vast majority of the papers, the operations research/management science methods had been used to provide prescriptive solutions.

Walton and Handfield (1996) analysed all the OM papers that appeared between 1990 and 1995 in four leading OM journal. They concluded that the primary area studied in the OM literature was still inventory and scheduling and with an OR/MS approach.

However, the examination undertaken by Filipini (1997) indicates that the situation may be changing. He examined recent pipeline research - the 1996 proceedings of the Decision Sciences Institute. He found that a number of issues were receiving less attention than in the past - inventory control, aggregate planning and forecasting. While the subjects of quality control, TQM and manufacturing strategy all received a lot of attention. He also examined the types of research methods used, finding that there was a greater use made of surveys than the traditional methods in particular simulation.

Filipini contends that Operations Management could benefit from the greater use of empirical research. Other writers, in recent years, have also called for the greater use of empirical research, especially the use of surveys (Flynn et al, 1990; Voss, 1995). Filipini feels that empirical research can make an important contribution to the development of OM knowledge and theories. He feels that greater attention should be given to analysing causal relationships between variables. Like Voss (1995) he supports the greater use of survey research to help build and test theories and models. The case study approach is considered by some to also help in the development of OM knowledge and theories (McCutcheon & Meredith, 1993). Overall, empirical research can make a contribution to the development and testing of theories. However, its usefulness, as Filipini points out, depends on the rigour of the methods and research instruments used. The research outlined in this thesis is in line with the call for the use of empirical research.

4.5 THE SCOPE OF THE RESEARCH INTO DELIVERY RELIABILITY

The research outlined in this thesis concentrated on the delivery reliability element of delivery performance. The research was exploratory in nature, it was carried out at the plant level (rather than at the company level) and focused on internal delivery reliability. Some of the survey research that has been carried out, such as the Futures survey (Ferdows & De Meyer, 1989) has been at the company level (rather than plant level). With the questionnaire being completed by the Chief Executive Officer or a similar senior manager. The problem with following this approach, in order to investigate specific areas of operational performance such as delivery reliability, are that senior managers may not have information about the actual performance of each of the companies' manufacturing operations. Also the information that is collected can be highly aggregated. Consequently, it is statistically difficult to investigate specific hypotheses involving plant to plant comparisons (New & Szwejczewski, 1995). Therefore, it is important to collect detailed performance information, such as delivery reliability data at the appropriate level - at the plant rather than aggregated company level.

Some studies have collected delivery reliability data based on the respondents' perception. However, New and Sweeney (1984) from their research into delivery reliability found that actual delivery reliability does tend to deviate from the perceived performance and is likely to be worse. Therefore, my research attempted to collect the monitored and reported delivery reliability of the plant and not the managers' perceptions of plant performance.

The research project did not concentrate on only one industry sector. An attempt was made to draw up a sample of plants from as many industrial sectors as possible. Some studies such as the global manufacturing practices project (Whybark & Vastag, 1993) were limited to a few sectors. This meant that any results could really be considered to extend beyond the industry sectors studied (Neuman, 1997). Also, the sample was not limited only to plants that were part of large manufacturing companies, the performance from small plants was also collected. Thereby ensuring that a more

representative sample of manufacturing plants was obtained.

Having examined the scope of the research let us now consider the issue of the research design.

4.6 RESEARCH DESIGN

This section covers the issue of research design - step 3 in the research process outlined in Figure 4.2. The first part of this section examines the various research methods open to researchers. These various methods are discussed and then the reasons for the final choice of methods used are given. The second part of this section outlines the stages of the data collection and analysis.

4.6.1 Research Methods

There are a number of research methods available to the researcher. The four basic types are: experiment, case study, historical review and survey (Jankowicz, 1991):

1. Experiment. The experimental approach offers a fruitful approach, since it apparently allows causality between variables to be precisely determined. In the experimental approach the researcher aims to set up a situation in which all the variables can be controlled or varied at will (Krausz and Miller, 1974). The researcher can hold all the variables constant except for one and by varying this one variable and monitoring changes in the resulting outcome(s), the resulting relationship between the variables can be carefully studied and documented. In essence what the researcher is doing is varying one specific independent variable whilst measuring the effects on the dependant variable, while keeping the other intervening variables constant. This approach is very helpful in determining the relationship between the variables. The advantage of the approach is that it can show a causal link between the variables involved. It is considered to be the best approach for testing causal relationships (Neuman, 1997). Also, experiments tend to be easier to replicate. The disadvantage is the difficulty of designing and setting

up an experiment to investigate a hypothesis. The approach is limited by the fact that experiments usually test one or just a few hypotheses at a time. Unfortunately this fragments knowledge and makes it necessary to synthesis results across many research projects (Neuman, 1997).

2. Case Study. The concept of the case study usually refers to an intensive examination of a single unit. Such a unit can be a person, a small group of people or a single organisation (Patton, 1987). The case study approach can be particularly useful when one needs to understand some particular problem or situation in great depth and where one wishes to obtain lots of rich information. A qualitative case study seeks to describe the unit of analysis (person, group or organisation) in detail, in context and holistically. The advantage of a case study is that it is comprehensive and informative about an organisation (Jankowicz, 1991). The disadvantage of the approach is the fact that the research can be subject to influence and interruptions arising from day-to-day events happening in the organisation. Also the researcher may unwittingly impact the area being studied, and so produce biased results. There is also the problem of accessibility to the organisation, various departments and individuals of interest. Another disadvantage of the approach is the fact that it does not allow for the generalisation of results (Patton, 1987). The approach is more suited to exploratory research rather than hypothesis testing. It can also be very time consuming if multiple sources of evidence within an organisation are required.
3. Historical Review. The historical review method is used to understand the past situation, and if need be, to relate it to the present situation (Jankowicz, 1991). The method can be used to study an organisations' performance (both past and present) relating to a specific issue, and in this respect it is similar to the case study approach. The problem with the historical review method is that in most cases the data collection is limited to secondary data only. However even if primary data based on interviews is obtained the data obtained may be incomplete since the human memory may not recall correctly past incidents and situations.
4. Survey. The survey approach involves the collection of questionnaire data from a number of respondents (Alreck and Settle, 1985). The data can be collected either at a fixed point in time (cross sectional) or at varying points in time (longitudinal

study) for comparative purposes. The data can be collected using a postal questionnaire, telephone or face-to-face (personal) interviews - Table 4.1 presents a comparison of the three types of data collection. Table 4.1 indicates that the personal interview method, compared to the other two methods, yields a high amount of data per respondent and also allows for a high level of interaction with the respondent. However it also is the most expensive in terms of data collection costs. On the other hand the mail approach is the lowest cost option and does not suffer from interviewer bias. However, it does have the drawback of not allowing for interaction with the respondent and yielding the lowest level of data per respondent when compared to the other two methods. The telephone method appears to fall between the two approaches.

	Personal	**Telephone**	**Postal**
Data collection costs	High	Medium	Low
Data collection time required	Medium	Low	High
Sample size for a given budget	Small	Medium	Large
Data quantity per respondent	High	Medium	Low
Reaches widely dispersed sample	No	Maybe	Yes
Interaction with respondent	Yes	Yes	No
Field worker training required	Yes	yes	No
Degree of interviewer bias	High	Medium	None

Table 4.1: Comparison of data collection methods (based on Alreck & Settle, 1985).

The survey approach is one of the most widely used approaches. It tends to be cheaper, quicker and broader in coverage than most of the other methods covered so far. The other advantage of the survey approach is the fact that it allows the researcher to explore relationships between variables for a large sample of respondents and also to generalise the results. The problem with the survey approach is that it does not have the same degree of control or allow for the level of in-depth investigation one gets from an experiment. In addition the survey data lacks the richness that the case study approach yields.

So which research method is the most appropriate? Alreck and Settle (1985) state that the decision about which method to use varies according to the nature and scope of the research, the source of data, the research questions and hypotheses and other constraints (such as time and resources) affecting the collection of the data. The research hypothesis and proposition to be investigated actually require a combination of research methods. At first glance the most appropriate way to undertake the research is via the use of a survey. Hypotheses' H1 and H2 could be investigated by the survey, which is suited to the testing of such hypotheses. However, the four propositions require greater in-depth investigation to be carried out, which cannot be done via the vehicle of a survey. For example, in order to investigate the focus of the performance measurement system the most appropriate approach is to interview the managers at a plant on a face-to-face basis. It would be difficult, if not impossible, to really get at the actual "focus" of the performance measurement system by simply asking for a survey questionnaire to be completed. The same is true of the focus of the management team. The case study approach is more appropriate for providing the richness and depth of analysis for identifying the interactions and explaining the outcomes in the manufacturing plant. So, in order to investigate the four propositions investigated the use of the case study technique would need to be used. While in the case of the two hypotheses the most appropriate approach would be via the use of the survey. Therefore, the final research design consisted of the use of the survey and the case study approach.

When it comes to the use of different research methods in Operations Management some writers (e.g. Meredith et al , 1989; Swamidass, 1991) recommend the use of the case study approach, while others (e.g. Voss, 1995; Filippini, 1997) support the survey method. Operations Management research into delivery reliability has tended to rely on the use of a single technique - either case study or survey. However in the case of this research project the use of only one method would not, in itself, effectively research all the issues. Figure 4.3 indicates the approach adopted for this thesis. The approach used for this research project bridges the gap between the two areas; the dual approach adopted by the author gives a more holistic and rich view of

the area being researched.

A number of writers point to the benefits to be gained from combining the two methods. Kaplan and Duchon (1988) argue that the survey and case study should not be viewed as polar opposites, as is sometimes done in Operations Management research, it is possible to integrate these two methods.

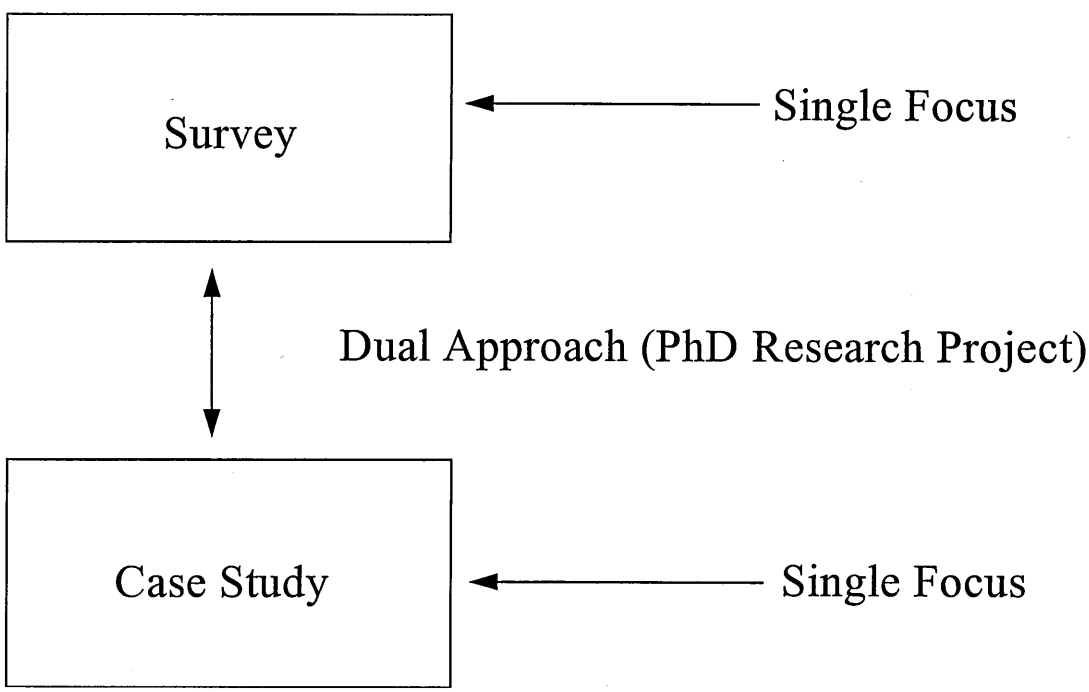

Figure 4.3: The dual approach to the research topic.

Combining these methods introduces both testability and context into the research. Bonoma (1985) makes the point that collecting different kinds of data by different methods from different sources provides a wider range of coverage that may result in a fuller picture of the unit under study than would have been achieved other wise. Mitroff and Mason (1982) also make the point that the use of different techniques helps to produce a more holistic approach. In addition, combining the two methods can provide a richer context basis for interpreting and validating results.

4.6.2 The Two Stages

The research consisted of two stages, Figure 4.4 shows the two elements. The first empirical stage of the research consisted of a survey of UK manufacturing plants. This was followed by the second empirical stage that consisted of a series of case studies.

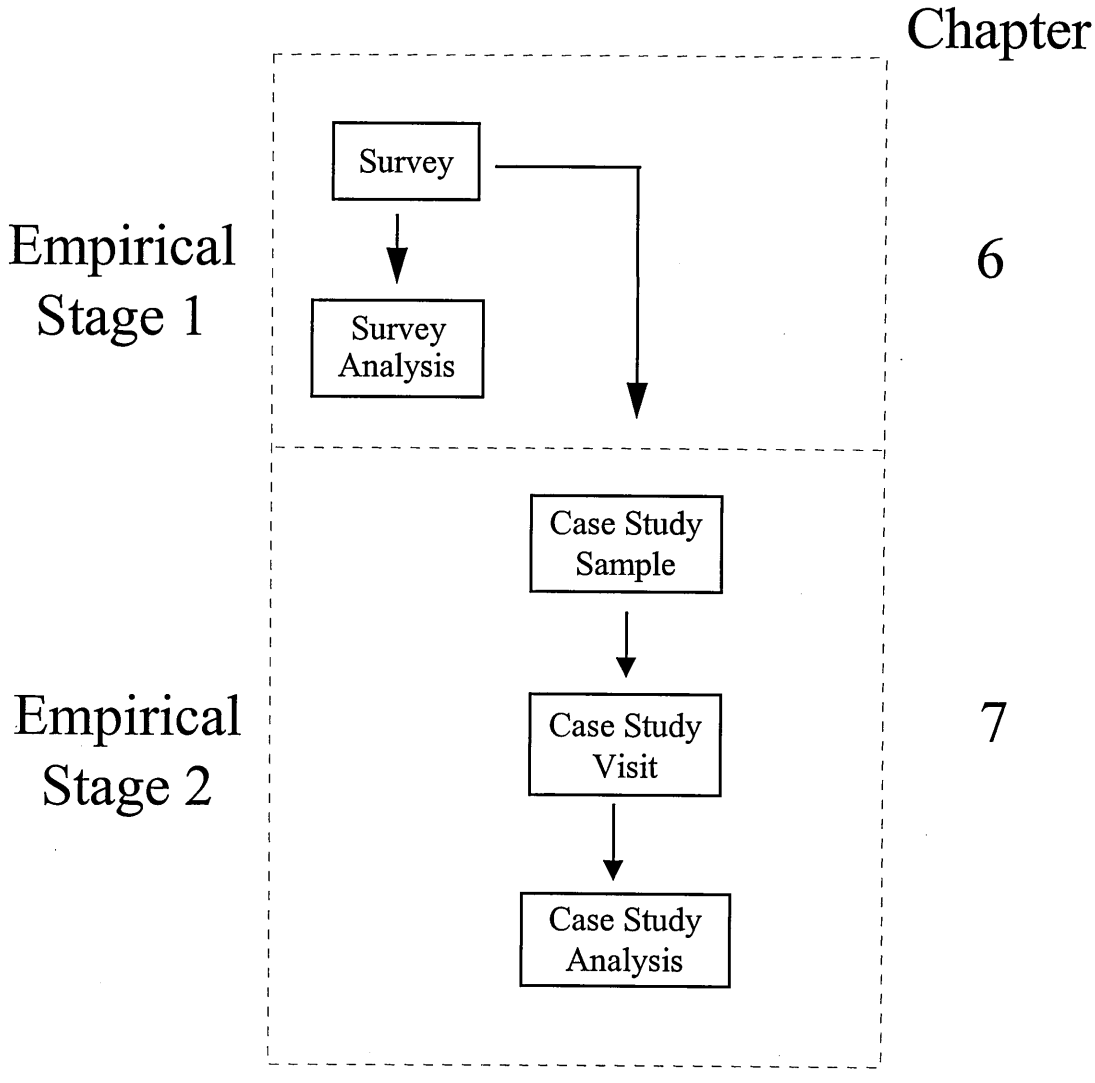

Figure 4.4: The two data collection stages of the research project.

Stage one involved the use of the survey method; a postal questionnaire was sent to a

large sample of UK manufacturing plants, ranging from building products to vinyl tiles. The returned questionnaires were then entered into a database and analysed using a statistical software package. The questionnaire data was analysed to see if hypothesis H1 and H2 could be accepted. The data was also analysed to determine if various other relationships between delivery reliability and a number of other plant related variables existed.

The second empirical stage of the research involved the use of the case study approach. The second stage involved using the plants that completed the questionnaire in the survey stage, to form a sample from which the case studies could be selected. The case study phase of the research consisted of visits to four pairs of plants (8 plants in total), the pairs were taken from the group of plants that completed the questionnaire. Each pair consisted of one plant with poor delivery reliability and one with high delivery reliability; since the questionnaire collected data about plant delivery reliability it was possible to select plants with good and poor performance. The use of a pool of responding plants allowed me to select the appropriate pairs of plants for the case study analysis. Also it gave the author the ability to control for possible key intervening variables and so select pairs of similar plants (similar except for the level of delivery reliability). Two pairs of plants were selected from the engineering sector and two pairs were selected from the electronics sector. The use of a sample pool also allowed a reserve list of plants to be created. The plants in this pool could be contacted should one of the pair not be prepared to in the research. Following the case study visits the data collected was analysed. The analysis helped to determine if any of the four propositions was correct.

4.7 CONCLUSION

This chapter has examined the research six questions that arose from the delivery reliability literature. The research questions covered a number of areas - in particular delivery quotation, part complexity, customisation, demanding customers, management focus and performance measurement system focus. Form the six research questions there arose two hypotheses and four propositions. A number of

research methods were examined in order to investigate the hypotheses and propositions. The final decision was to use two methods; survey and case study. This two method approach was chosen because of the diverse nature of the hypotheses and propositions. The survey approach appeared to be the best way to investigate the hypotheses, while the detailed nature of the propositions required the case study approach to be adopted.

The survey stage of the research involved the use of a postal survey targeted at manufacturing plants (all industry sectors). The returned questionnaires were used to build a sample of plants from which the case study plants were selected (for the case study stage of the research). The case study plants were selected from the sample as pairs; two pairs from the Engineering industry sector and two pairs from the Electronics sector . Each pair contained one plant with poor delivery reliability while the other unit had good delivery reliability.

CHAPTER FIVE

METHODOLOGY

5.0 INTRODUCTION

The previous chapter outlined the research approach adopted. It also outlined the overall design and explained why the mixed research method approach was used. The research approach consisted of two stages, the first involved the use of a survey and the second involved the use of the case study approach.

This chapter will cover in detail the survey and the case study approaches. The first half of this chapter (Section 5.2) will cover the survey element of the research. The chapter will examine the different types of survey techniques available and why the postal survey approach was chosen. It will then go on to discuss questionnaire design and the procedure followed for mailing out the questionnaire. The chapter will also cover the statistical techniques used to analyse the returned postal questionnaires.

The second half of this chapter (Section 5.3) will examine the case study approach that formed the second element of the research. The case study element involved an examination of 4 pairs of plants. Each pair contained one plant with poor delivery reliability and one with high levels of delivery reliability. Two sets of pairs came from the engineering sector and the other sets of pairs came from the electronics sector. The chapter covers the selection of the cases, the data collection method and the analysis approach used.

5.1 SURVEY AND CASE STUDY

The two empirical stages of the research were briefly explained in Chapter Four. The first empirical stage of the research used data taken from a survey of UK manufacturing plants. The survey was used to examine hypotheses H1 and H2. In addition, as Figure 5.1 shows, the survey covered a number of other areas of the conceptual model such as supplier delivery reliability.

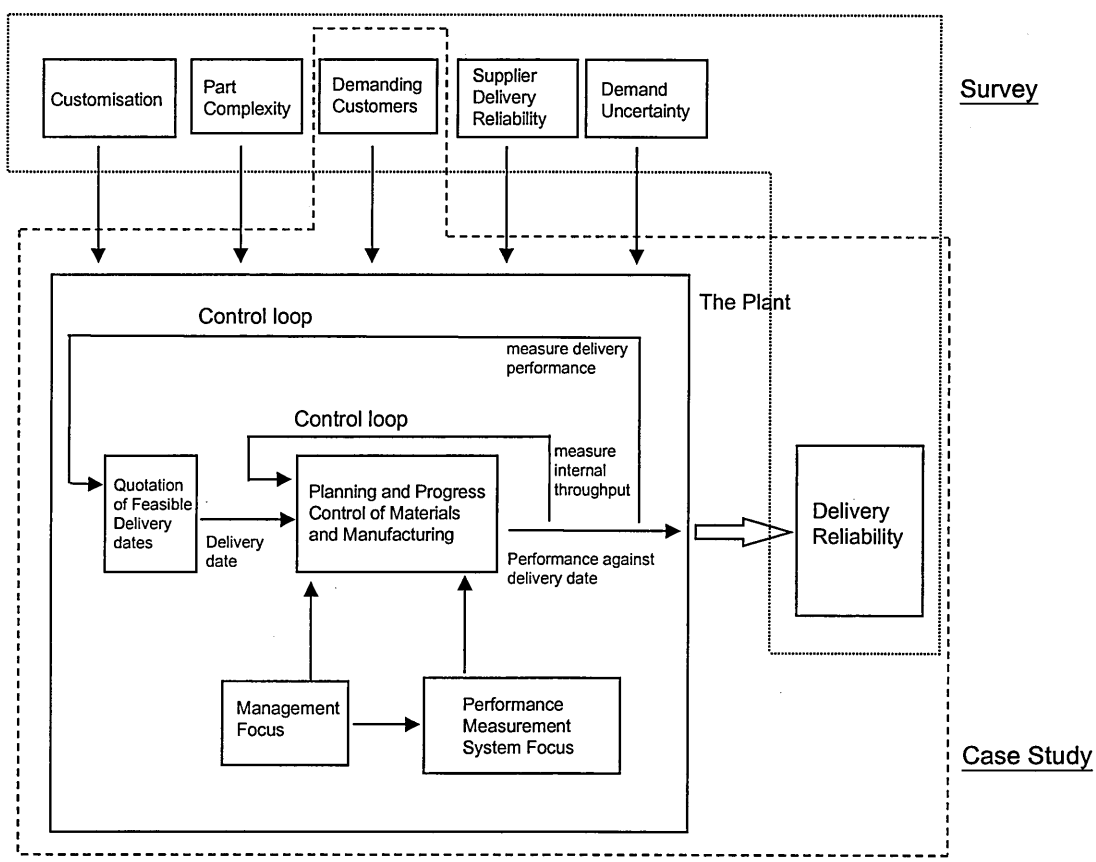

Figure 5.1: The areas of the conceptual model covered by the survey and case study.

The case study stage involved using some of the plants that responded to the survey to form a sample from which the case studies could be selected. The case study stage of the research examined the four propositions presented in Chapter Four. The second stage investigated a number of areas of the conceptual model as shown in Figure 5.1

The case study stage of the research consisted of visits to four pairs of plants. Each pair consisted of one plant with poor delivery reliability and one with high delivery reliability.

Using this approach it was possible to examine the two hypotheses and four propositions. In addition it was possible to investigate all the elements of the conceptual model.

5.2 THE SURVEY STAGE

This section will cover in detail the survey stage of the research. The objective of the survey was to test hypotheses H1 and H2 and determine if they could be accepted. The survey was used to examine a number of other relationships. This section will discuss the various types of survey methods available and why the postal survey was used. It will then cover the issue of questionnaire design. The section will then cover sampling, the mailing procedures and the approach to analysing the returned questionnaires.

5.2.1 The Survey Method

A survey is a method of primary data collection based on communications with a sample of individuals (Alreck & Settle, 1985). The approach can be done either at a fixed point in time (cross sectional) or at varying points in time (longitudinal study) for comparative purposes. The advantages of the survey method are that if correctly designed and administered it provides a quick, inexpensive, efficient, and accurate means of assessing information about a population. A large sample of respondents can provide the basis for statistical analysis and help to determine the degree of association between the dependent variable and a range of independent variables. The analysis can enable firm conclusions to be drawn from the survey data, and the

findings to be generalised. A large sample also helps to raise the level of reliability and validity of the research (Alrech & Settle, 1985).

In Chapter Four, the basic reasons for choosing the survey approach were given, but no explanation was given for the type of survey method that was used. There were three survey methods that could have been used for this research (Alreck & Settle, 1985), as follows:

- Postal survey — self administered by the respondent.
- Face-to-face interview — self administered personally or through the use of a third party.
- Telephone survey — interview via the telephone personally or via the use of a third party.

The telephone survey approach was rejected because the detailed information requested cannot be obtained during a telephone conversation. The respondent may not have all the information at hand, for example they may not have information about the number of products manufactured at the plant or the proportion of customised products.

The face-to-face interview approach was rejected because of the nature of the data that needed to be collected, some off which could take time to obtain. This approach was also rejected because of the expense and time that would be involved in interviewing a sufficiently large sample of manufacturing plants.

The postal survey was chosen for a number of reasons. The method was comparatively cheap and would allow for the collection of data from a large cross section of UK manufacturing plants. The intention was to collect data from manufacturing plants in various industry sectors not simply one sector, for example engineering. This would help to build an understanding of delivery reliability across industries. The mail survey was an efficient way of getting to the plants that measured

delivery reliability and manufactured predominantly to customer order. This method was also chosen because it would allow the respondent time to be able to collect the information that was requested in the questionnaire, for example information about the current amount of product customisation activity. Let us first examine how plant delivery reliability is measured and then go onto to look at the issue of questionnaire design.

5.2.2 Measuring Delivery Reliability

Let us examine how plant delivery reliability is measured. The most usual method for measuring plant delivery reliability is to compare the actual date when the order was despatched against the date is was planned (due) to be despatched (Voss, 1980; New & Sweeney, 1984; Maskell, 1991). A delivery is considered to be 'on-time' if it is despatched on or prior to the set despatch date (due date). Therefore if all the orders despatched within a particular time period were on-time, then the figure for delivery reliability would be 100% (for that period).

This method has a number of advantages for the manufacturing plant (Voss, 1980; Maskell, 1991). Firstly it provides a single number of delivery reliability. Having a single number visible in the manufacturing plant can be an important step in helping to develop a corporate attitude that delivery is important. Secondly a single number makes goal setting easy. Finally, the measure can be calculated using existing information in the plant.

There are a few issues that should be covered at this point relating to the measurement of delivery reliability. Care needs to be taken when considering which despatch date should be used. There may be a difference between the date originally requested by the customer and the date actually quoted by the plant, the plant may quote a later date. Should the date used be the original customer's requested date or the actual date quoted by the plant? Using the later date and not the customers requested date might

mean that the plant sets itself an easier target to hit. The customer's order is not despatched when he wants it, yet the plant achieves on-time delivery against its own due date.

Another issue is the fact that a delivery reliability measure is often based on the despatch date. Such an approach assumes that the product will be delivered to the customer and there will be no delays or problems in transit. However, as New and Sweeney (1984) indicate in their Total Delivery Management Model, transportation to the customer is an important element of delivery. As they point out this element should not be ignored because delays do occur and can cause late delivery to the customer's premises. If one view's delivery reliability from the customer's point of view, the product is not actually delivered until the customer receives it. Maskell (1991) makes the point that it may be difficult to gather the information in order to be able to determine what date the order reached the customer because the plant may not have control over the carrier. Another issue is the question of the period the date covers. Should delivery in the same week, day or hour be considered to be on-time?

The measurement of delivery reliability may sometimes suffer from the problems outlined above. However, it does not mean that every company has its own unique way of measuring delivery reliability (White, 1994). Maskell contends that the measure is commonly based around the planned despatch date. So there is a degree of consistency in terms of the delivery date a plant's performance is measured against. Evidence from the Best Factory Award visits appears to support this view. Also, evidence from the visits also indicates that the despatch date is a day rather than a week[1]. So, again a degree of consistency exists.

In order to measure delivery reliability it was decided to use the approach used in the Best Factory Awards questionnaire. The questionnaire asked what the delivery

[1] Evidence from the Best Factory visits suggest that plants with high levels of delivery reliability do not have very sloppy measures of delivery reliability, for example using the week rather than the day in the calculation.

reliability against a quoted due date was for those items supplied on a quoted lead time. This particular approach had been used over a number of years without any difficulties. The approach has also been outlined in New & Szwejczewski (1995).

5.2.3 Questionnaire Design

Designing a questionnaire is an important task, since a properly designed questionnaire can elicit the precise information that the researcher wants. However, a poorly designed questionnaire will provide data that can be confusing, difficult to analyse and therefore of little value. Also a poorly designed questionnaire can be prone to systematic error. Systematic error is a potentially avoidable error that distorts the results in a systematic manner (Neuman, 1997). This type of error can impact the validity and reliability of a survey. Reliability for researchers means that the method of conducting a study or the results of it can be reproduced or replicated by other researchers. The most fundamental test of reliability is "repeatability", namely the ability to get the same data values from several measurements made in a similar manner (Alreck & Settle, 1985). Validity is the degree to which the survey measures what, and only what, it is supposed to measure (Alreck & Settle, 1985). Systematic error caused by, for example, a poorly worded questionnaire may cause many respondents to answer in a particular way. This will result in the survey being systematically pulled in a particular direction with the end result of low validity. If the survey suffers from low reliability then the results obtained will be questionable (Neuman, 1997). However, Neuman (1997) makes the point that perfect reliability and validity are virtually impossible to achieve, rather they are ideals to be striven for. For him the maximisation of reliability and validity should be pursued as far as is possible. The validity and reliability of the survey results depend on the way every aspect of the survey is planned and executed, but the questionnaire design and the way the questions are asked are the most essential components (Alreck & Settle, 1985).

There is a vast body of literature relating to questionnaire design (e.g., Oppenheim, 1966) which was consulted during the process of designing the questionnaire. Since questionnaire design is a well-known topic I will only present the salient points from the literature.

One of the first steps in questionnaire design is to clearly define the focus of the research (Moser & Kalton, 1972). The questionnaire should elicit the response that one is most interested in without much extraneous information being collected as well.

Another important element in questionnaire design is to ensure that the questions are both clear and unambiguous - to ensure that the words have a common meaning for everybody completing the questionnaire (Alreck & Settle, 1985). It is important that good instructions are given with the questions (Oppenhiem, 1966). The manner in which the questions are expressed can all too often introduce bias (Alreck & Settle, 1985). Questions should not be loaded (i.e. do you advocate a lower speed limit to save human life) or leading (i.e. don't you see some danger in the new policy). Every attempt should be made to ensure that the questions are checked to ensure that no bias or error has crept in, which could jeopardise reliability and validity.

It is important to carry out pre-testing of the questionnaire, to ensure that the respondents understand the questionnaire and to check if systematic bias is present. Pre-testing also allows the researcher to examine the data, to determine if the questionnaire is providing the kind of information that is being sought.

Suitable steps should be taken to attempt to ensure that a good response is obtained (to minimise non-response bias[2]), this can be done by ensuring that the questionnaire is well designed and easy to follow. The questionnaire should be sent out with a

[2] Non-response bias is a systematic affect on the data reducing validity that results when those with one type of opinion or condition fail to respond to a survey more often than do others with different opinions or conditions (Alreck & Settle, 1985).

personalised letter and a reply paid envelope. The level of response can also be increased via the use of offering a motivation to subjects to respond and also the use of reminder letters.

5.2.4 The Questionnaire

It was decided to use the vehicle of the Best Factory Awards Audit questionnaire as a means of obtaining the data required for the survey stage of the research. The alternative of mailing out a separate questionnaire was considered, however such an approach suffered from the drawback that it requested information that a single respondent may not possess and would require the assistance of other departments to obtain. Therefore, the likelihood of a low response rate and partially completed questionnaires was quite high. Also the already collected some of the data (e.g. delivery reliability) required for this research project and so only a few extra questions needed to be added. In addition, the Best Factory Questionnaire had already been piloted and was found to be reliable.

There are a number of special characteristics of the awards and the questionnaire that make it suitable for this research project:

1. Specific unit of analysis. The unit of analysis is the plant and is specifically stated as such thereby ensuring consistency of the data collected.
2. Multiple respondents. The questionnaire requires cross-functional data and in most cases although one individual is responsible for co-ordinating the input, the data is supplied by the relevant managers (e.g. accountant, production planning and control etc.). This overcomes the problems of role, lack of knowledge and appropriateness of the individual mailed.
3. Quality of the Data. There is every reason to believe that the quality of the data collected is high, because if a plant is selected for a judges' visit the management team will be required to substantiate all the entries. So there is every reason for the management team to supply factually correct data. Also, the auditing of some of

the completed questionnaires, over the years, has not uncovered any major discrepancies (New & Szwejczewski, 1995).

It may be argued that the plants that take part in the Best Factory Awards are not representative of UK manufacturing. The plants that take part may be more representative of those that are above average in terms of performance. However the research was concerned with those plants that predominantly make-to-order and measured their delivery reliability. Given the focus of the research, the plants that enter the awards were the most appropriate.

The Management Today Best Factory Awards run in association with Cranfield School of Management have been running since 1992, the original awards started in the mid 1980s. The awards are open to any manufacturing "plant" in the UK; a "plant" being defined as a relatively self-contained unit with its own management staff, which can be identified either by separate facilities, by separate products, or by a separate management structure (New & Szwejczewski, 1995). The awards scheme is aimed at all manufacturing plants and the scheme also includes a small business award to encourage small businesses to enter.

To enter the awards, a plant is required to complete a detailed 14-page questionnaire. The questionnaire is very comprehensive in terms of the data collected about the plant. An important feature of the Best Factory Awards questionnaire is the type of data collected. The questionnaire does not collect perceptual information, unlike the Global Futures or "Made in the UK" PROBE survey (New & Szwejczewski, 1995). The questionnaire collects actual raw data, so for example the questionnaire collects information about the level of scrap rather than whether it is higher or lower than the industry average on a scale of 1 to 5.

The original Best Factory Questionnaire captured a lot of the data required for the project. However, some areas were not covered such as supplier delivery performance.

Consequently the questionnaire had to be revised to include the following additional topics:

- The major factors that facilitate the good delivery performance of the plant
- Supplier delivery performance
- The influence of the major factors on quoted delivery dates

During the process of including additional questions, close attention was paid to the wording of the questions to ensure clarity and lack of bias (as recommended in section 5.2.2). The questionnaire was also pre-tested with a number of manufacturers and academics.

The Best Factory Awards questionnaire (the revised version - see Appendix A) had a number of sections each dealing with different elements of plant operation. The questions required for this research project were inserted into the most appropriate sections.

The first section (Section A) of the questionnaire covered general plant profile data, such as the plant parent (e.g. UK Parent, Japanese Parent etc.), and the size of the plant (Square Feet). The second section (section B) collected data about a number of areas. Firstly, it elicits the degree to which the plant is making customised products. The questionnaire obtains information about the proportion of output that is standard product, customer specific products to repeat order and the amount that is unique customer specific (customised). The section also identifies if the plant is making capital, intermediate or consumer goods. The questionnaire determined the number of products manufactured by the plant, the manufacturing lead times involved and the set-up times in the factory. The questionnaire also identified the degree to which the plant was making for stock and/or to order. The section also included a question about what were considered to be the major factors behind the plant's good delivery reliability. It also included a question about the influence of major factors on quoted delivery dates. The section contained a question about supplier delivery reliability.

The third section of the questionnaire obtained information about the value of manufacturing output and the manufacturing cost structure (for example material costs). The fourth section obtains information about the plant inventory levels: raw material, work-in-process and finished good levels.

The fifth section covered the number of employees employed at the plant, their age profile and absenteeism levels.

The sixth section covered product innovation, the time it typically took to bring a new product innovation to market, and the number of new products introduced. The seventh section collected information about plant performance, in particular formally measured performance such as delivery reliability.

This updated version of the questionnaire was the one that was used for the survey stage of the project.

It has been suggested that a long questionnaire (more than 6 pages) does not encourage respondents to complete them and so produces a low response rate (Alreck & Settle, 1985). However, in the case of the Best Factory Awards questionnaire this was less of a problem because of the incentive (the free benchmarking report) for the manager to complete the questionnaire.

5.2.5 Sampling

Some surveys make use of sampling, the concept of sampling simply means taking part of some population to represent the whole population (Alreck & Settle, 1985). The alternative to sampling is enumeration i.e. counting the whole population. The major reason behind sampling is economy. To survey every individual in a population via enumeration is usually too expensive in terms of money, time and personnel. With

sampling the researcher gets a set of cases (or sample) from sampling that is more manageable and cost effective to work with than the whole population of all cases. If sampling is carried out properly it lets the researcher collect data about a variable from a small set of cases, but generalise accurately to all the cases (Neuman, 1997). However, the researcher cannot just use any sample to generalise accurately. The sample must be selected according to precise procedures.

There are two approaches to sampling: probability and non-probability sampling (Kidder and Judd, 1987). Table 5.1 shows the different types of probability and non-probability sampling.

Sampling Technique	**Definition**	**Comments**
1. Simple	Select people based on true random procedure	Laborious and time consuming, but provides most reliable sample procedure
2. Systematic	Select every nth person (quasi-random)	Independent of researchers preference or prejudices
3. Stratified	Randomly select people in predetermined groups	Laborious and time consuming
4. Cluster	Take multistage random samples in each of several levels	Laborious and time consuming
5. Haphazard	Select anyone who is convenient	The result is only applicable to the sample studied
6. Quota	Select anyone in predetermined groups	Conclusions drawn are limited to the sample studied but tentative implications for others may be suggested
7. Purposive	Select anyone in hard to find target group - using ones own judgment	Only tentative generalisations may be made
8. Snowball	Select people connected to each other	

1 to 4 is probability sampling, 5 to 8 is non-probability sampling

Table 5.1: Sampling Techniques (based on Neuman, 1997).

With probability sampling every item in the population has a known non-zero probability of selection. The best known form of probability sampling is the simple random form of sampling, with random sampling each member of the population has an equal probability of being selected. However, with non-probability sampling, the probability of any particular member of the population being chosen in unknown. In the case of non-probability sampling the selection of sampling units is arbitrary, as the researcher relies heavily on personal judgment. It should be noted that there are no appropriate statistical techniques for measuring random sampling error for a non-probability sample. Thus, projecting the data beyond the sample may be statistically inappropriate. For the researcher the ideal is to go for random sampling with a relatively large sample size. However, the reality, of course, is that the researcher is faced with a number of constraints namely time, money and administrative support. These constraints make it very difficult and expensive to get a truly random sample.

In a number of cases, researchers have been forced to adopt non-probability sampling. According to Mitchell (1985), 79% of the research he looked at utilised non-probability sampling. In addition, Godyer (1988) makes the comment there is not much difference between the research based on probability and non-probability sampling in terms of how representative the sample was to the population.

In order to undertake the research, data from certain types of manufacturing organisations was required. The goal was to obtain data from a sample of plants who were:

- Mainly make-to-order
- Measured delivery reliability
- Came from across a range of industry sectors - but in particular included plants from the engineering and electronics sectors

It is very difficult to isolate plants that meet these selective criteria. Not every plant manufactures mainly to order, some make for stock. Also, not every plant actually

measures its delivery reliability (New & Myers, 1986). So, due to the difficulty of obtaining data from plants that met such selective criteria and for reasons of time and money it was appropriate and necessary to go for a purposive sample (Neuman, 1997). The purposive sample uses non-probability sampling where the researcher uses his/her own judgment to select the most appropriate sample to be studied (Kidder and Judd, 1987). The use of a purposive sample means that only tentative generalisations can be made. However, Dane (1990) contends that in the case of exploratory research it is possible to avoid using a probability sampling approach. While Neuman (1997) points out that purposive sampling is an acceptable kind of sampling for special situations. Purposive sampling is appropriate in three situations.

- Firstly, the researcher wants to use it to select unique cases that are especially informative.
- Secondly, the researcher may use purposive sampling to select members of a difficult to reach specialised population.
- Thirdly, another situation for purposive sampling occurs when a researcher wants to identify particular types of cases for in-depth investigation.

The last two of the above apply in the case of this research project.

In order to obtain the data from specific manufacturing organisations that the research required it was decided to use the plants that entered the Best Factory Awards as the basis of the sample. In order to ensure that the sample was as representative as possible, previous entrants to the awards were sent a questionnaire and asked to complete it. The questionnaire was also be mailed to manufacturing managers who had attended courses at the Cranfield School of Management. This approach was used to help increase the response rate and thereby increase the level of reliability.

The target was to obtain at least 100 completed usable questionnaires (from plants that met the selection criteria), such a large sample of completed questionnaires should

yield an improved level of reliability[3]. Following the advice of Dixon, Bouma and Atkison (1987), a smaller sample of completed questionnaires would be acceptable, the minimum sample size was 30.

5.2.6 Mailing Procedure

The revised Best Factory Questionnaire was mailed out to the sample along with a covering letter, which outlined the benefits of completing the questionnaire (especially the offer of a free benchmarking report). A reply paid envelope was also included to help improve the response rate.

In addition to the plants on the database, all the plants who entered the awards in the year would also complete the revised questionnaire and so would be included in the sample that was used in the analysis.

A concern with postal surveys is non-response error i.e. error caused by significant difference between those that do respond and those who do not; often response error impacts the reliability of the research. A number of actions were taken to reduce this problem such as the use of a personalised letter, the use of a reply paid envelope, free benchmarking report and assuring anonymity and confidentiality to all those who completed a questionnaire.

All the questionnaires that were completed and returned were then entered into the SPSS data file ready for the data analysis step of the research. Let us now cover the subject of data analysis.

[3] Sirkin (1995) points out that the Law of Large Numbers states that if the size of the sample is sufficiently large (no less than 30), then the Central Limits Theorem will apply even of the population is not normally distributed. The Central Limits Theorem assumes that the population we are studying is normally distributed. But if the sample is large enough, the population distribution need not be normal. When the sample is large enough we can relax the normality assumption.

5.2.7 Data Analysis

It was decided early on in the research project to use the SPSS for Windows data analysis software. The questionnaire had been designed for ease of data entry into the SPSS data entry file. The data collected was then subjected to various forms of data analysis.

Firstly, univariate analysis (one variable analysis) was performed on a number of variables to be found in the questionnaire. Through the compilation of a range of frequency tables it was possible to show the types of plants that had replied and their general characteristics such as the level of delivery reliability, number of products manufactured, number of people employed, etc. However, univariate analysis tells us nothing about the relationship between variables, to do that we have to carry out bivariate analysis. Bivariate analysis examines the connection between two variables. The bivariate approach was used to investigate possible links between the dependent variable, delivery reliability and a number of independent variables. This analysis was used to determine the nature and direction of the linkage. Several techniques were used to determine what relationships were present in the data, the techniques were: chi-square test, t-test, analysis of variance, and regression analysis.

The chi-square test is used to ascertain that the probability of the observed relationships between two variables did not occur by chance (Alreck & Settle, 1985). The test is used for category data, with one variable identified as the independent and the other as the dependent (Alreck & Settle, 1985). The null hypothesis is that no relationship exists between the two variables. The null hypothesis is rejected if the test indicates that a relationship is found to exist. The test rests upon comparing the observed frequencies with the 'expected' frequencies that would be obtained if there was no relationship between the two variables. The resulting statistic from the test indicates if the null hypothesis should be accepted or rejected, at a given significance level.

One technique for hypothesis testing is the t-test (Alreck & Settle, 1995). The t-test is a method for testing the statistical difference of two means. If the test indicates that the two means are equal then the null hypothesis is held to be true and we must suppose that we have drawn two samples from the same populations (McCall, 1994). If, however, the test indicates that the null hypothesis cannot be accepted, then we can say that the two samples do in fact have different means and have been drawn from two different populations.

Another bivariate technique that was used was the analysis of variance method (ANOVA), this approach was used to test the statistical difference between two or more means (McCall, 1994). In this approach two estimates of the population variance are computed, one is calculated between the group means - this is the mean square between groups, and is sensitive to whatever differences exist between group means. The other estimate of the population variance is calculated within each of the groups and is pooled across the groups. It is called the mean square within groups and is not sensitive to whatever differences exist between group means. If the null hypothesis is true (i.e. several groups have the same population mean) then the ratio of the between-groups to the within-groups mean square, known as the F ratio, should vary around the value of 1.00 by sampling error. However, if the F ratio is large, it probably reflects the influence of group differences on the numerator (the between-groups mean square), and the null hypothesis should be rejected. The way to determine (if the null hypothesis is rejected) which of the means are significantly different from each other, is to use the Tukey's Honestly Significant Difference (HSD) (McCall, 1994).

Regression analysis is a technique that can be used to measure the relationship between a continuous independent variable and a dependent variable that is also continuous and to assess the significance of this relationship (Alreck and Settle, 1985). When the analysis includes just one independent variable, the more precise term for this statistical method is linear regression, when there is more than one

independent variable it is called multiple regression. Regression analysis generates a regression equation and the r-square value. The regression equation is the formula for computing a predicted value for the dependent variable, based on the value of the independent variable - the equation includes the constant and a regression coefficient. To predict the value of the dependent variable for a given case/respondent when only the value of the independent variable is known, the researcher need only multiply the regression coefficient by the value of the independent variable and then add the constant. The regression coefficient is simply the slope of the regression line. When the coefficient is positive the line slopes upwards; when the value of one variable increases, so does the other. When the coefficient is negative, the line slopes downwards and so the relationship is inverse - when one value goes down, the other increases. The regression analysis produces a coefficient called the r-square. The r-square value (ranging from 0.0 to 1.0) indicates the proportion of variance in the two variables that is shared between them. The r-square value indicates the percentage of variance in the dependent variable that is "explained" by the value of the independent variable, it is an indication of how much influence the independent variable has over the dependent variable. The closer the r-square is to 1 the greater the influence.

5.3 THE CASE STUDY STAGE

The previous section (5.2) covered the survey stage of the research, let us now examine the second stage. The second stage of the research involved the use of the case study approach. The objective of the case study approach was to examine the four propositions:

P1. In plants where the production planning department determines the delivery quotation, the level of delivery reliability will be high.

P2. In plants where the customers have expectations of high levels of delivery reliability, the level of delivery reliability will be high

P3. In plants where the management team is predominantly focused on delivery reliability, the level of delivery reliability will be high.

P4. In those plants where the performance measurement system has delivery reliability as a key area of focus, levels of delivery reliability will be high.

The case study approach, with its ability to explore in depth the various aspects of how the manufacturing plant is actually being run, meant that it was ideally suited for investigating the various propositions.

The case study approach has often been criticised on the grounds of "how can you generalise from a few case studies?". Such an opinion is misplaced. While it is true that statistical generalisation is not possible from a small number of cases, that is not true of analytical generalisation (Yin, 1989). Here the case study is not a sample but rather a method of linking the material to be found in the case to theoretical propositions as a means of assessing the logic and structure of these theoretical components. Cases are used in a similar way to the way in which the laboratory investigator selects the topic of a new experiment. Multiple cases can be considered to be multiple experiments, as Yin states:

> "The method of generalisation is 'analytical generalisation' in which a previously developed theory is used as a template with which to compare the empirical results of the case study. If two or more cases are shown to support the same theory, replication may be claimed" (Yin, 1989 p38).

The multiple case study approach was used in this research. This approach has the advantage over a single case study in that the evidence from multiple cases is considered more compelling and the overall study is therefore regarded as more robust (Yin 1989). The disadvantage is that the conduct of a multiple case study may require

extensive resources of time and money. The use of multiple case studies makes no claim to conform to the demands of a sampling logic. Instead the intention was to select a sufficient number such that sufficient grounds were available for making useful comparison and contrasts, and drawing analytical inferences. Cases need to be carefully selected (Yin, 1989) so that they either predict similar results (they are a literal replication) or they produce contrary results but for predictable reasons (they have theoretical replication) . The use of multiple cases follows what Yin calls replication logic

> "The replication logic is analogous to that used in multiple experiments ... Thus, if one has access to only three cases of a rare, clinical syndrome in psychology or medical science, the appropriate research design is one in which the same results are predicted for each of the three cases. Thereby producing evidence that the three cases did indeed involve the same syndrome. If similar results are obtained from all three cases, replication is said to have taken place" (Yin, 1989 p53).

What Yin recommends is that a few cases are used for literal replication whereas another number is used to pursue a different pattern of theoretical replication. Now if all the cases turn out as predicted then the researcher would have very compelling support for the initial set of propositions. If however, some of the cases are in some way contradictory, this initial set of propositions would need to be revised and as he recommends re-tested with another group of cases. Pattern matching is a popular approach in theory testing studies. The rival hypotheses can simply consist of the null hypothesis. Yin (1984) acknowledges that pattern matching has a weakness in terms of rigor. As he states one of the difficulties with pattern matching is the fact that it leaves the issue of which hypothesis best matches the data, to be somewhat subjective. So what he advocates is comparing sufficiently clearly differentiated hypotheses to allow an "eyeball test" to determine which best matches the data. Miles and Huberman (1994) recommend the use of tables to help with the pattern matching

process. However, as Miles and Huberman acknowledge, such displays are still in essence summaries of qualitative data, whose interpretation is of necessity judgmental rather than mathematical.

5.3.1 Validity and Reliability in the Context of the Case Study Approach

Yin (1989) mentions four tests that are appropriate for assessing the value of a case study approach. The ability to pass these tests has a major impact on the perceived quality of the analyses of the cases. The four tests are:

1. Reliability: demonstrating that the operations of a study - such as the data collection procedure - can be repeated, with the same results

2. Construct Validity: establishing correct operational measures for the concepts being studied

3. Internal validity: establishing a causal relationship, whereby certain conditions are shown to lead to other conditions

4. External validity: establishing the domain to which a study's findings can be generalised.

A number of tactics (recommended by Yin, 1989) were used to ensure that the approach followed, during the research, would pass the above tests.

1. Reliability. The achievement of a high degree of reliability minimises the effects of errors and biases by fully describing the method followed in each case so that a researcher on the same case could arrive at similar conclusions. A high level of reliability was sought by the use of a case study protocol in which all the plants and

informants were subjected to the same sequence of entry and exit procedures and the same interview questions.

2. Construct Validity. The case studies contain some data that is "soft" and some which can be quantified. The use of closed questions and scales allows for the operationalisation of some of the variables to be studied. However, some of the concepts created may be based on interpretative data and therefore liable to bias caused by subjective assessment. The possible problem of construct validity was overcome by the use of multiple sources of evidence within each case being studied (Yin, 1989). Where contradictions were identified further clarification was sought and the contradiction rectified.
3. Internal Validity. The case study approach can cause spurious relationships to arise. The use of multiple case studies and the analytical technique of pattern matching were used to help overcome this problem (Yin, 1989). Also the use of multiple sources of evidence would help to overcome the problem.
4. External Validity. This problem was overcome by the use of the multiple case design, whereby a pair of plants came from the same industry sector and were similar in size and manufacturing operation.

Closely allied to the issues of reliability and validity in case studies, is that of bias. Bias can be found in case study research as well as survey. Huber and Power (1985) point to three major sources of bias:

- Perceptual bias
- Respondents lack data
- Poor research procedure

The level of bias due to poor research procedures was reduced by the use of the research protocol. In the case of the lack of data, the respondents were notified about the nature of the data that was to be examined and if it was not available during the interview the information was obtained and discussed at the end of the day. While a

good researcher is aware of the various sources of bias and is able to reduce it if not eliminate it, it is extremely difficult to avoid bias creeping in because of the perceptual bias of the researcher of the patterns in the data (Miles & Huberman, 1984). It is only natural for the researcher to look for positive confirmation of his/her findings rather than refutation. In order to overcome this area of bias Yin (1989) and Miles and Huberman (1984) recommend some counter measures such as openness to contrary findings. Also to overcome the problem of bias the data analysis was not started until all the case study data was collected to avoid the researcher drawing conclusions as the data collection proceeds (and biasing the subsequent interviews and data collection towards a particular direction). Miles and Huberman (1984) advise researchers to hold the conclusion that may arise during data collection until they can be seen to be fully grounded in the research, otherwise researcher bias is being introduced into the data collection process. This advice was followed by the researcher.

5.3.2 Triangulation

Some research literature points to the importance of triangulation (Denzin, 1978). The triangulation metaphor is from navigation and military strategy, where multiple reference points are used to identify an object's exact position. The multiple view points allow for greater accuracy. Similarly management researchers can improve the accuracy of their judgment by collecting data on the same phenomenon from different points of view. The method of triangulation can capture a more complete holistic and contextual portrayal of the unit or units under study (Jick, 1979). There are different types of triangulation e.g. source, time and method. Triangulation of sources requires the researcher to develop evidence from different sources, these might include literature, or other media, as well as interaction with several informants, particularly different types of informants. It has been recommended that data is collected from different sources for, example from different levels of the organisation. Triangulation of methods demands that the researcher test an interpretation in data gathered using

several different methods, i.e. video, audio tape, photographs. Time triangulation can be used where data is collected on the same research object at different times.

Although there are several different types of triangulation available to the researcher, the approach does place great burdens on the researcher (Yin, 1989). In order to cope with the burden it is useful to prioritise possible areas of triangulation between those which are:

1. Vital - to secure fundamental basic integrity of data, and gain theoretical insight.
2. Valuable - triangulation measures which have major benefit in counteracting bias and for generating insight but vary in whether these are manageable in relation to the overall research task (and therefore selectively actioned).
3. Peripheral - areas where triangulation might be attempted but either with low benefit or where the costs in terms of making the research approach unwieldy are either high or potentially insuperable.

For the purpose of this research project triangulation across sources was used (as recommended by Wallendorf & Belk, 1989) - data about a particular area/issue was collected from a number of different individuals. The triangulation of source would also include data from different levels in the organisation.

5.3.3 Unit of Analysis

A key component of the case study approach is the unit of analysis - what the case actually is (Yin, 1989). Without knowing what the case is, the researcher does not know how to limit the boundaries of the study. Since the case study approach allows the collection of data from many perspectives and for time periods of undetermined duration, the researcher must clearly define the unit of analysis at the outset of the study. The primary unit of analysis, or the organisational boundary of the case, in the case of this research project was the manufacturing plant.

5.3.4 Pilot Case Study

An initial pilot was carried out at two manufacturing plants. The pilot consisted of interviews with the manufacturing manager and the production planning manager. The interviews were carried out using a semi-structured questionnaire. As a result of the pilot the approach to the research was changed, in particular the paired sample approach was introduced. In addition the number of individuals interviewed was increased and the questionnaire was revised, with more issues being covered.

5.3.5 The Final Case Study Approach Used in The Project

The manufacturing plants that completed the Best Factory questionnaire formed a large sample pool from which the case studies could be drawn. This approach was used because, firstly the questionnaire that each plant completed contained information about plants' delivery reliability and other variables that were necessary for the case study selection and pairing process. Secondly, the plants were more likely to be open to taking part in the research, when compared to plants that had to be approached cold. The case study stage of the research consisted of 8 case studies - 4 pairs.

The plants that formed the 4 pairs were selected from those that had completed the revised Best Factory Awards questionnaire. The multiple cases were not chosen at random, rather they were selected to fit particular categories. The case studies were taken from two industry sectors:

1. Electronics
2. Engineering

Two pairs of plants were selected from each industry sector. The plants that made up the sample all had the same type of manufacturing systems: either batch or line production. Process or job shop manufacturers were excluded from the analysis. The two industry sectors were chosen because they had in the past represented a large proportion of the plants that entered the Best Factory Awards and so ensured the author had a large pool of plants top chose from.

In order to raise the generalisability of the cases a number of independent variables that could possibly impact the delivery reliability of the plants were controlled for. The variables that were controlled for were:

- The level of product complexity
- Level of product customisation
- The proportion "make-to-order" and "make-for-stock"
- The general size of the plant - number of plant employees

The plants were selected to form pairs, each pair had similar characteristics in terms of product complexity, level of customisation, etc. However, one of the pair had high delivery reliability, while the other had low delivery reliability. This allowed for comparison of the plants without the concern that exogenous factors were having the real impact on delivery reliability differences.

It was very difficult to select two plants that exactly matched on all the variable but it was possible to achieve an acceptable degree of similarity. For example the two plants would have broadly similar proportion of make-to-order, make-for-stock. i.e. plant A had a split 90% make-to-order and 10% to stock while plant B had a split of 95% make-to-order and 5% make-for-stock.

A total of 8 case studies (4 pairs) were carried out. Each case study pair also varied in the degree of complexity, so one pair in the engineering industry contained plants with low complexity while the second pair contained those with high complexity. The

same selection procedure was carried out in the electronics industry sector. Also a reserve list of plants was maintained, in case some of the plants declined to take part in the research.

The researcher may be taking a risk in trying to determine the acceptance of a proposition from just eight cases, however this is feasible from a theoretical rather than a sampling perspective due to replication logic (Yin, 1989). Certainly at the level of falsifying and originating propositions, the choice of several cases (i.e. eight) is potentially sufficient to generate some conclusions (Yin, 1989).

Once the sample of plants was created they were approached by the researcher. The management of the plants were contacted by letter and asked if they would take part in the research project. The offer of a free focused benchmarking report was used as an incentive to encourage the plants to take part. The contact letter was targeted at the most senior individual at the plant, it outlined the research project and the individuals the researcher wanted to interview. The letter was followed up with a telephone call to arrange the visit date and to discuss in more detail which individuals should be interviewed, the areas of discussion and any information that was required. To increase the reliability of the case studies a research protocol was used when undertaking the research. Yin (1984) states that a case study protocol is a major tool for increasing the reliability of the research through its structuring of the procedures and rules which are important with a multiple case study design. The protocol sets out the general procedures that will be followed, the key individuals to be interviewed, the research instrument to use and the supplementary material to be collected.

Following Yin's advice (1984), the same approach was taken for each visit, in terms of the type of people interviewed, the questions asked and the way the production facilities were examined. The visit involved interviews with the key personnel in the

plant and a tour around the production facilities. The informants who were interviewed during the case study visit were as follows:

Plant Manager
Production planning manager
Manufacturing Manager
Marketing or Sales manager
Purchasing manager

The subjects covered during the interviews were as follows:

Production Planning
Performance Measurement System
Quoting Delivery Due Dates
Market/Customer Requirements
Control of Orders on the Shop Floor
Product Manufacturing
Problems on the Shop Floor

A questionnaire was used for the interviews, administered by the author. The questionnaire was structured, but containing predominantly open ended questions. Different questions were asked of the different individuals but to allow for triangulation and verification of the data some parts of the questionnaire were common between some of the individuals. In addition to carrying out the interviews with the managers, relevant documentary evidence such as delivery reliability reports were obtained. Also any factory performance charts displayed on the shop-floor were noted and recorded.

5.3.6 Analysis Process

The case study approach may yield rich, full, holistic and real data, however it comes in such large quantities that it can overload the researcher (Miles, 1979). As Eisenhardt (1989) points out, qualitative research tends to generate a mountain of messy data that can be difficult to analyse effectively. Therefore it is important to adopt a structured approach to deal with all the data.

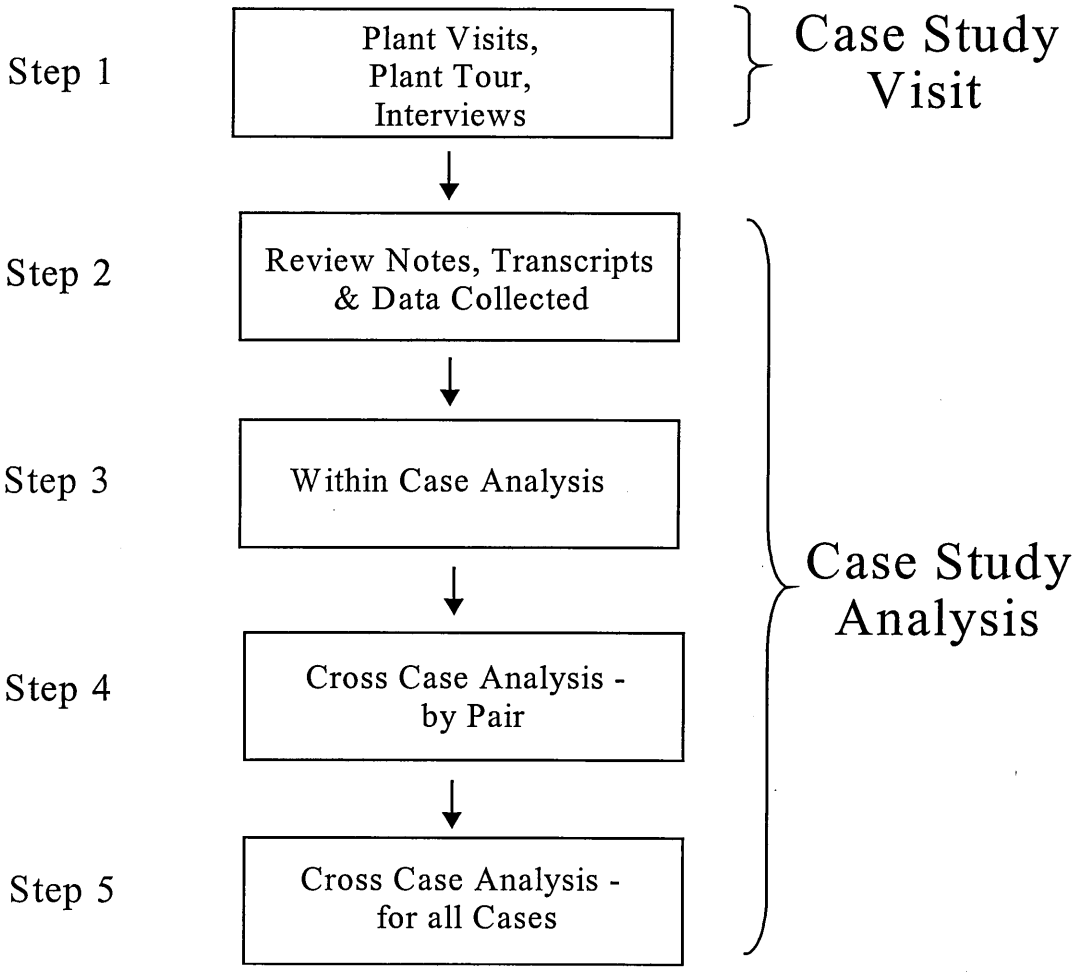

Figure 5.2: Case Study data collection and analysis process - 5 steps.

A structured approach to the data analysis was developed based upon the various approaches taken by several writers (Miles & Huberman, 1984), (Yin, 1989), (Eisenhardt, 1989). In this section the step by step process of analysis employed is

described. The data collection and analysis process is broken down into 5 steps (as can be seen in Figure 5.2).

The 5 steps were as follows:

Step 1. During the plant visit the interview data was captured by audio-tape recording and also by taking of notes. A tour of the production floor was made and a note was made of the performance measures displayed for the employees. The key performance measurement reports were also examined and a request was made to take a copy of this information away for further study.

Step 2. Immediately after each of the visits the field notes were checked for clarity and foot-notes were added to explain any jargon used. The audio-tape data was transcribed. All the interview notes and the transcripts were then collated into a file - one for each case (plant).

Step 3. Taking each case in turn, the within case analysis was then undertaken. This process started with the data being reviewed by the process of reading and re-reading, in order to build up a complete picture of what was happening in the plant. This iteration process helps the researcher become intensely familiar with the case as a stand alone entity. An important part of this process of analysis was not to allow predetermined structures to force themselves on the data at an early stage, but rather to review the case and see what emerges from the data. This approach helped to combat any possible bias. During this process of review the method of writing memos was used to make a note of observances and possible relationships detected in the data. Yin (1984) recommends putting information into different arrays or into chronological order as tactics that might be employed by the researcher to bring order to the mass of raw data.

The responses of managers to common questions were collated in tabular form, to help aid the understanding of the case and also help with the later cross case comparison (Miles & Huberman, 1984).

Following on from the analysis the complete case was written-up. The write-up took the form of a narrative organised around specific topics, questions and plant activities:

> "These write-ups are often simply pure descriptions, but they are central to the generation of insight .. because they help researchers to cope early in the analysis process with the often enormous volume of data." (Eisenhardt, 1989 p540).

This in-depth analysis and case write-up step is important because:

> "This process allows the unique pattern of each case to emerge before the investigator pushes to generalise patterns across cases. In addition, it gives investigators a rich familiarity with each case which, in turn, accelerates cross-case comparison" (Eisenhardt, 1989 p540).

Step 4. Having written the narrative for the case it was then possible to carry out cross case comparison for each pair of cases. Cross case analysis involved the use of a structured comparison of the cases (Eisenhardt, 1989; Miles & Huberman, 1984). The approach was to select various issues or dimensions and to look for the similarities and differences between the two cases. Tables and data arrays were used in the process (Yin, 1984; Miles & Huberman, 1984).

At this point the pattern matching approach to analysing the data was used; it involved comparing an empirically based pattern with a predicted one (or with several alternative predictions). In the pattern matching approach, if the patterns coincide, the results can help a case study to strengthen its internal validity (Yin, 1989). Using this

method it was possible to analyse all the case studies using a cross case comparison approach. Thereby determining if the predicted patterns did exist for the plants with the high performance levels and what the pattern was for those with low performance levels. The pattern matching approach was carried out for each of the pairs of plants. The result of each comparison (for each pair of plants) was documented.

Step 5. Having carried out the cross case comparison for each pair of cases the next step was to review all the cases together. The similarities and differences between all the plants were examined. The result of this comparison was also documented. The cross case comparison was also used to examine if any of the four propositions were relevant.

5.4 CONCLUSION

This chapter has presented a detailed explanation of the two empirical stages of the research project. The first empirical stage of the research involved the use of a postal survey. The Best Factory Awards questionnaire was used to obtain the relevant information for the research. The data collected with the questionnaire was then used to examine the relevance of the two hypotheses presented in Chapter Four.

The second empirical stage of the research was the use of the case study approach. The plants that completed the Best Factory questionnaire were a source from which the case studies were drawn for the second part of the research. This particular approach was adopted because of the need to be very specific in the plant selection and pairing - the sample of plants could be trawled to be able to select the specific plants required in terms of delivery reliability, industry sector and other specific plant characteristics. Four pairs of plants were drawn from the sample of plants, two pairs from the electronics sector and two pairs from the engineering sector. Each pair of plants contained one plant with high delivery reliability and one plant with low delivery reliability. In addition a number of independent variables that could impact

delivery reliability were controlled for. The level of customisation, product complexity and number of employees was controlled for, so each pair of plants had similar levels of complexity, customisation etc. This particular approach allowed for a comparison between the pairs of plants to identify the factors behind poor delivery reliability and also to extend the comparison across all the plants.

Each of the plants was visited and several managers were interviewed. The same approach to the plant visits was used in each case. A comparable group of managers was interviewed at each of the plants and the same questions were asked of the relevant managers at each plant. The analysis of the case study data followed a structured approach, starting with individual case analysis, followed by cross case comparison of each pair of plants, and then finishing with a review of all the plants.

The next chapter (Chapter Six) will cover the analysis of the survey data and Chapter Seven will cover the case study stage of the research.

CHAPTER SIX

QUESTIONNAIRE SURVEY RESULTS 1994-96 DATA

6.0 INTRODUCTION

This chapter presents the results of the analysis of the survey data. The chapter starts by outlining the general characteristics of the plants that formed the sample analysed. The chapter then goes on to present the analysis of the relationship between plant delivery reliability and a number of key variables. As part of this section the two hypotheses will be tested and the results discussed.

6.1 THE SAMPLE

In order to have the benefit of working with a large sample size it was decided to use the Best Factory Awards data for a three year period, 1994 to 1996. Since the research was about the issue of delivery reliability, the sample of plants that was used in the analysis consisted of:

1. those plants that measured their delivery reliability
2. and those plants that manufactured a proportion of their output to order (or were totally making to order).

A total of 409 plants formed the sample used in the analysis[1]. The final sample did not contain any duplicate plants, i.e. those that had entered the awards in more than one year.

Table 6.1 indicates the plant ownership profile for the sample, for the period 1994 to 1996. Table 6.1 indicates that the majority (65.0%) of the plants were owned by a UK parent. The second largest group of plants (12.0%) was owned by a US parent, closely

followed by a group of plants with a Continental European parent (10.3%). However, only 2.4% of the sample were owned by a Japanese parent company.

Parent	Percent of Plants
A UK Parent Company	65.0
A Continental European Parent Company	10.3
A Japanese Parent Company	2.4
A US Parent Company	12.2
Other Foreign Parent Company	3.7
Joint UK/Foreign Parent Company	6.6
(n=409)	100.0%

Table 6.1: Profile of plant parent.

The next table shows the total number of full-time employees working at the plants. Table 6.2 indicates that the majority (53.1%) of plants employed 200 or less full-time employees, although 17.6% of the plants employed more than 500 employees. Overall the sample was not over-represented by plants with a large number of employees (i.e. more than 1000).

No. of Employees	Percent of plants
1 - 200	53.1
201 - 500	29.3
501 - 1000	13.2
1001 - 2000	2.7
Over 2000	1.7
Total	100%
(n=409)	

Table 6.2: The number of full-time employees in the plant.

[1] The original sample consisted of 645 plants.

A chi-squared test was used to determine if the sample used in the research was different from the total sample of plants (from which it was taken) for the period 1994-96. The test indicated that there was no difference between the two groups in terms of the plant parent characteristics or the number of employees. In addition, an analysis of variance was used (on the final sample) to determine if the delivery reliability was significantly different between the three years - the results indicate that no significant difference in performance was found to be present.

The questionnaire obtained information about the plants current level of delivery reliability, this information is presented in Table 6.3. The figures presented in Table 6.3 show that only 8.3% of the plants achieved 100% on-time delivery reliability. However, the majority of the plants achieving more than 90% on-time delivery, whilst 17.9% of the plants achieved delivery reliability of 80% or less.

Delivery Reliability	**Percent of plants**
Less than 60%	5.3
60 - 69.9	3.4
70 - 79.9	8.1
80 - 89.9	14.2
90 - 94.9	16.6
95 - 96.9	17.1
97 - 98.9	15.4
99 - 99.9	11.3
100%	8.3
(n = 409)	100.0%

Table 6.3: Delivery reliability of the sample.

Let us now go on and examine the relationship between delivery reliability and a number of plant related variables.

6.2 THE RESULTS - THE KEY VARIABLES

This section examines the relationships that were found to exist between a number of independent variables and delivery reliability. The section also examines if either of the two hypotheses can be accepted.

6.2.1 Reasons Behind Good Delivery Reliability

One of the areas the research explored was to determine which were the main factors that helped the plant to achieve good delivery reliability. The respondents were asked about which major factors facilitated good delivery reliability in the plant. They were asked to rank seven factors in order of importance (in facilitating good delivery reliability in their plant). The factors were as follows:

1. Excess capacity
2. A reliable supply chain
3. Workforce flexibility
4. Reliable processes
5. Quick changeovers
6. Responsive planning and control system
7. Other

The results of the rankings are shown in Table 6.4, where a ranking of 1 indicates high importance and a ranking of 7 indicates least importance.

Rank	Excess capacity	Reliable Supply chain	Workforce flexibility	Reliable processes	Quick change-overs	Planning & control	Other
1	5.3	24.3	12.1	18.2	1.8	31.1	7.9
2	4.5	21.9	18.7	25.3	5.3	20.3	3.7
3	5.3	20.3	23.0	22.7	10.0	15.8	2.6
4	6.1	14.0	24.8	19.5	15.6	17.4	2.6
5	14.5	13.5	15.0	9.5	32.5	10.6	4.5
6	47.5	5.0	5.8	4.0	25.9	4.0	6.9
7	16.9	1.1	0.5	0	9.0	0.8	71.8
Total (n=407)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 6.4: Ranking of the major factors that facilitate good delivery reliability in the plant.

The results presented in Table 6.4 indicate that the respondents considered the major factor behind good delivery reliability performance was a responsive planning and control system, 51.4% of the plants ranked as the number 2 or 1 (with 31.1% of the plants ranking it as number 1). The second most important factor was having a reliable supply chain, 46.2% of the plants ranked it as 2 or 1. The third most important factor was the presence of a reliable process. The fourth most important factor was workforce flexibility. Table 6.4 also shows that very few of the respondents attributed their good delivery reliability performance to having excess capacity or the ability to carry out quick changeovers.

These results indicate that the respondents consider that a responsive planning and control system are important to helping them achieve good delivery reliability. However, the analysis is based on the respondent perceptions and not on actual performance. It may be that plants with good delivery reliability value a responsive planning and control system as highly as plants with poor performance. Therefore, an

investigation was undertaken into the difference in delivery reliability between those who ranked a responsive planning and control system as high, and those who ranked it as low. The plants were separated into three groups (based on the ranking given to planning and control):

1. High - rank 1 or 2
2. Medium - rank 3 or 4
3. Low - rank 5, 6 or 7

The delivery reliability for the high and low group was compared using a t-test.

	High Group	**Low Group**	**Sig.**
Delivery reliability	88.5	89.0	0.826

Table 6.5: Comparison of delivery reliability for the high and low group.

The results of the analysis are presented in Table 6.5. The results indicate that there was no significant difference in the delivery reliability of the two groups of plants. Plants that ranked a responsive planning and control system as the most important factor that facilitated good delivery reliability did not achieve any higher levels of delivery reliability than plants that ranked it as a less important factor.

6.2.2 Degree of Customisation and Delivery Reliability

The survey data was analysed to determine if the hypothesis (H1) concerning the relationship of customised products and delivery reliability could be accepted. Hypothesis H1 states that:

> Plants that manufacture a low proportion of their output as customised products are likely to have a higher level of delivery reliability than those

plants that manufacture a higher proportion of their output as customised products.

The questionnaire captured information about the degree to which the plants manufactured standard or customised products (products made to a unique customer specific design). In order to investigate hypothesis H1 it was necessary to investigate the extent of customisation that a plant was prepared to undertake. The definition of customised products did not include those items which although based on a customers unique specification were manufactured by the plant on a repetitive basis. The questionnaire was designed to collect information about the proportion of output (at manufacturing cost) that was to a unique customer specific design. The survey findings therefore allowed the author to test hypothesis H1. Survey findings on customisation were obtained from companies that customised products from 0 to 100%[2].

In order to examine if there was a relationship between the proportion of customised products and delivery reliability linear regression analysis was used. The regression was carried out with the proportion of output devoted to unique customer specific design as the independent variable and plant delivery reliability as the dependent variable. Table 6.6 shows the regression equation that was derived.

In Table 6.6 the R square represents the proportion of the variance of the dependent variable (delivery reliability) that was explained by the regression equation. The table also shows the value of B that is the partial regression coefficient and its standard error (S.E of B).

[2] The case study analyses complemented this research but only studied companies that customised products to a maximum of 25%.

R Square	0.062				
Adjusted R Square	0.059				
	F = 26.15	**Sig.** = 0.0000			
Equation Variable	**B**	**S.E of B**	**Beta**	**T**	**Sig. T**
Unique customer design	-0.160	0.031	-0.249	-5.113	0.000
Constant	90.403	0.842		107.34	0.000

Table 6.6: Regression - Level of customisation and delivery reliability.

The Durbin Watson statistic was calculated to test for autocorrelation. The value of the statistic was 1.93 (with N=399) which was above the critical value and so supported the hypothesis that autocorrelation was not present.

The results of the regression show that there is a significant negative relationship between the extent of customisation and delivery reliability[3]. This indicates that plants that manufacture a low proportion of customised products do have a higher level of delivery reliability performance. While the plants that manufacture a high proportion of customised products have low levels of delivery reliability. The results from the analysis indicate that hypothesis H1 is correct; the null hypothesis (that there is no relationship) can be rejected.

The result of the analysis also indicates that around 6% of the variance in the level of delivery reliability is explained by the equation. The percentage variance that was explained by the equation was low, and indicates that there were many other factors that affected delivery reliability. This low result is to be expected since the model outlined in Chapter Four points to the influence of a number of variables. Therefore, we would expect the percentage of the variance explained by one variable to be low.

[3] The result was significant (at below the 0.001 level).

However, an important finding is the fact that the relationship between delivery reliability and the level of customisation was found to be significant.

The literature, examined in Chapter Three did indicate that customisation has a detrimental impact on delivery reliability. The results of the regression analysis appear to agree with the assertions made in the literature. It appears that manufacturing a high proportion of customised products is associated with low delivery reliability performance.

A manufacturing plant that has to deal with a high proportion of customised products has a difficult task to carry out when compared to a plant making very few customised products. With customised products most customer orders tend to be different from each other. Consequently, at the quotation stage it may be difficult to determine exactly how long it will take to make the product (Dinitz, 1990). This means that the delivery date quoted may be unrealistic.

At the detailed planning stage the different routing and processing times of the various products make it difficult to produce a plan the factory can produce. Since the routing and processing times vary between products it is difficult to accurately predict where the capacity problems will occur. A plan that seemed, on the face of it, to be achievable may experience delays on the shopfloor. In addition to the problem of planning, once on the shopfloor there may be unexpected stoppages due to unforeseen quality problems. Since the product has not been made before it may suffer from a greater number of quality problems. The results of these capacity constraints and quality problems may be that the actual manufacturing lead time is longer than initially estimated and so delivery reliability may decline. The plant making standard products does not have these problems and so it is likely to achieve higher levels of delivery reliability, when compared to the plant making a high proportion of customised products.

6.2.3 Complexity and Delivery Reliability

The second hypothesis (H2) that was investigated related to the relationship between part complexity and delivery reliability. Hypothesis H2 states that:

> Plants that manufacture relatively complex products are likely to have lower levels of delivery reliability than plants that manufacture relatively simpler products.

The questionnaire collected information about the products being manufactured by the plant, in particular the number of parts used. The measure of part complexity was defined in terms of the number of different components used in the main product manufactured by the plant. To examine the relationship between product complexity and plant delivery reliability a linear regression analysis was carried out, with product complexity as the independent variable and delivery reliability as the dependant variable. The linear regression did not produce a relationship, indicating that delivery reliability was not related to product complexity. The results indicate that in the case of hypothesis H2 the hypothesis was rejected and the null hypothesis was accepted i.e. there was no relationship between the two variables.

The literature suggests that plants that manufacture simple products achieve better delivery reliability than those that make much more complex products. However, the results of the regression do not support these assertions. There may be several reasons why the regression analysis did not identify any relationship between part complexity and delivery reliability. Firstly, it may be that it was process complexity that was having the major impact. Another possible reason for the lack of a relationship being identified was the fact that the measure of part complexity used may have been a poor measure. The measure used may not have been correctly measuring the level of complexity that was experienced by each plant. Consequently, no relationship appeared to be present.

6.2.4 Customers and Delivery Reliability

Let us now examine the impact of the customer, specifically the influence of the customer on the quoted delivery date. Plants that determine the quoted delivery date without the customer having a lot of influence are likely to be able to quote the delivery date they felt they could realistically achieve. Plants where the customer dictates the delivery date, may be forced to quote delivery dates that they may not have enough capacity to achieve.

So, did those plants where the customer had a major influence on the quoted delivery date achieve a lower level of performance than those plants where the customer had less influence?

The questionnaire collected information about the extent to which the quoted delivery date was determined by customer requirements (the value of the variable ranged from 0% to 100% determined by customer requirements). To examine the relationship between the extent to which the quoted delivery date was determined by the customer and plant delivery reliability, linear regression analysis was used. The results of the regression are show in Table 6.7.

R Square	0.091				
Adjusted R Square	0.089				
	F = 40.69	**Sig.** = 0.0000			
Equation Variable	**B**	**S.E of B**	**Beta**	**T**	**Sig. T**
Demanding Customers	0.132	0.021	0.302	6.379	0.000
Constant	80.677	1.397		57.752	0.000

Table 6.7: Regression equation - influence of customers and delivery reliability.

The independent variable was the extent to which the quoted delivery date was determined by customer requirements and the dependant variable was the level of delivery reliability. The Durbin-Watson statistic was calculated to test for autocorrelation. The value of the statistic was 1.99 (with N=408) which was above the critical value and so no correlation was present.

The results of the regression equation show that there is a significant positive relationship between the extent to which the customer requirements determine the quoted delivery date and the plant delivery reliability. It appears that where the customer has a major say about the quoted delivery date the plant will also achieve high levels of delivery reliability. However, when the plant has the major influence on the quoted delivery date then delivery reliability will be poor.

The results also indicate that around 9% of the variance in the level of delivery reliability was explained by the equation. The percentage variance that was explained by the equation was low, indicating that other factors were impacting delivery reliability. However, as I have indicated this is what one would expect to see, delivery reliability is impacted by a number of variables, not just one.

If the plant is operating in a market where the customer has the major influence on the delivery date it may be that this influence extends to forcing the plants to achieve that delivery date. The customers who have a major influence on the delivery date quotation are likely to be very demanding and therefore would demand that the quoted delivery date was honoured. The regression analysis does suggest that those plants where the delivery date is predominantly influenced by the customer also achieve those dates since their delivery reliability is high.

The traditional view was that the plant that determined the quoted delivery date itself (without the customer having a lot of influence) was able to set realistic delivery

dates. This implied that its delivery reliability would be high. However, the research results suggest that this view is incorrect. The research results indicated that the plant that determined the delivery date (where the influence of the customer was low) actually achieved poorer delivery reliability than the plant where the customer was the main influence on the delivery date.

6.2.5 Suppliers and Delivery Reliability

The literature (Cunningham & Dale, 1983; Britchford, 1985) indicates that late delivery by suppliers may have a negative impact on the plant delivery reliability. The questionnaire collected information about suppliers delivery reliability. The impact of supplier delivery reliability[4] on plant performance was investigated using the survey data. To examine the relationship between supplier delivery reliability and a plant's own delivery reliability a linear regression analysis was carried out. Table 6.8 shows the results of the regression, where the supplier delivery reliability is the independent variable and the plant delivery reliability as the dependant variable.

R Square	0.121				
Adjusted R Square	0.117				
	F = 34.26	**Sig.** = 0.0000			
Equation Variable	**B**	**S E of B**	**Beta**	**T**	**Sig. T**
Supplier delivery reliability	0.388	0.066	0.348	5.853	0.000
(Constant)	55.630	5.746		9.681	0.000

Table 6.8: Regression equation - supplier delivery reliability and delivery reliability.

[4] Around 61% of the plants in the sample actually measured their suppliers delivery performance. A t-test was carried out to check if there was any difference in plant delivery performance between those that measured their suppliers delivery performance and those that did not. The t-test results indicated that there was no significant difference in the delivery performance of the two groups.

The Durbin-Watson statistic was calculated to test for autocorrelation. The value of the Durbin-Watson was 2.098 (with n=251) which was above the critical value and so no auto-correlation was present.

The results of the regression show that there was a significant positive relationship between the supplier delivery reliability that the plant experiences and the plant's own level of delivery reliability. The plants that experience high levels of supplier delivery reliability also had high levels of delivery reliability themselves. While those with low levels of supplier delivery reliability had low levels of delivery reliability themselves.

The results of the regression analysis indicate that nearly 12% of the variance in the level of delivery reliability was explained by the equation. Overall the results of the regression are supported by the literature, which suggests that poor supplier delivery is strongly associated with poor delivery reliability. Having suppliers who deliver on time (high levels of supplier delivery reliability) means that the plants' production is not delayed due to the lack of raw materials or components. With no delays in the production processes it means that products are likely to be made by their planned due date, and therefore customers' orders are delivered on-time. Poor delivery on the part of the suppliers results in production being delayed due to the late arrival of components and raw materials. These delays may feed through to causing delays in the production of customer orders by their delivery date. Poor supplier delivery reliability can feed through to produce poor plant delivery reliability.

6.2.6 Uncertainty and Delivery Reliability

The survey analysis also investigated the extent to which the uncertainty experienced by the manufacturing plants was related to the delivery reliability of the factory. The specific element of uncertainty that was investigated was the uncertainty of customer demand levels. Demand uncertainty was measured by classifying the unpredictability

of customer demand on a scale of 1 to 5 for the next six months (where 1 was highly predictable and 5 was highly unpredictable). The measurement of uncertainty was based around the perceptions of the managers. Swamidass and Newell (1987) state that the Organisational Behaviour literature suggests that only through managers' perceptions does the degree of uncertainty become known to the organisation. Therefore it is appropriate to use a perceptual measure of uncertainty in an exploratory study but recognised that different managers in different businesses will assess the level of uncertainty to an inconsistent scale. The measure of uncertainty was based around that of predictability. This approach had also been used by Swamidass and Newell (1987) for their measurement of demand uncertainty.

In order to determine if the level of delivery reliability was related to customer demand levels a Pearson Correlation was carried out. The unpredictability of customer demand was correlated against plant delivery reliability. The results of the correlation are shown in Table 6.9.

	Delivery Reliability
Customer demand uncertainty	- 0.1344 (sig = 0.007)

Table 6.9: Correlation between market demand uncertainty and delivery reliability.

Table 6.9 shows that a negative correlation exists between the two variables, the correlation coefficient was -0.1344 (n=407) and the relationship was significant at below the 0.01 level. The results of the correlation indicate that plants where the level of customer demand unpredictability was high, the level of delivery reliability was low. However, when customer demand was predictable, plant delivery reliability was also high.

A sudden unpredictable change in demand can impact the load placed on the factory. A sudden increase in load may result in an overload for some of the work centres, causing queues to rise and manufacturing lead times to increase (and for their variability to increase). The result of an increase in manufacturing lead times may be that some delivery dates are missed and ultimately delivery reliability suffers. In addition, a plant that experiences high levels of demand unpredictability will find it difficult to carry out forward planning, especially capacity planning.

6.2.7 Market Requirements and Delivery Reliability

Another area that was explored was the influence of the market for high levels of delivery reliability. The plants with high levels of delivery reliability may be operating in markets where reliable delivery dates are very important to customers. This may result in the plant having a high level of delivery reliability. The questionnaire obtained information about the importance of several market factors. The respondents were asked to rank several criteria in order of relative importance to the customer (for the product group with the largest output at manufacturing cost). One of these criteria was the importance that the customer placed on the reliability of delivery dates .

The Spearman rank correlation test was used to determine if there was any relationship between delivery reliability and the importance of reliable delivery dates to the customer. The Spearman rank correlation was used because the importance of reliable delivery dates was a ranked variable.

	Delivery Reliability
Importance of reliable delivery dates	- 0.0116 (Sig = 0.850)

Table 6.10: Correlation between market requirements and delivery reliability.

Table 6.10 shows the results of the correlation. The results of this correlation were not significant, there appeared to be no relationship between the importance placed on reliable delivery dates and the level of delivery reliability achieved. The results indicate that plants may have high levels of delivery reliability and yet supply customers who are perceived not to rank reliable delivery dates very highly. One of the reasons why there was no correlation between the two variables might be because the importance of reliable delivery dates was based on the managers' perceptions (of how important the customer ranked it) rather than what level of importance was really attached by customers. The managers may have been misrepresenting the actual attitudes of the customers.

6.2.8 Multiple Regression

The linear regression analysis has identified a number of relationships. The question still remains to be answered which ones are the key ones? To answer this question, a multiple regression was run to determine which variables had the greatest impact on delivery reliability. The variables that were used in the analysis were:

Demanding Customers
Proportion of Customisation
Supplier Delivery Reliability

A multiple regression was run using the three factors as the independent variables and delivery reliability as the dependent variable. The results of this regression are shown in Table 6.11. The Durbin-Watson statistic was calculated to test for autocorrelation. The value of the Durbin-Watson was 2.079 (n=243) which was above the critical value and so supported the hypothesis that no autocorrelation was present.

The results of the multiple regression indicate that as expected all the three variables impact delivery reliability. The regression equation shows that a reduction in the

proportion of customised products, an improvement in supplier delivery reliability, and an increase in the influence of the customer on delivery reliability is associated with higher levels of delivery reliability performance.

R Square	0.300				
Adjusted R Square	0.291				
	F = 34.03	**Sig.** = 0.0000			
Equation Variable	**B**	**S E of B**	**Beta**	**T**	**Sig. T**
Proportion of customisation	-0.234	0.037	-2.521	-6.399	0.000
Demanding customers	0.322	0.063	0.288	5.129	0.000
Supplier Delivery Reliability	0.104	0.023	0.250	4.583	0.000
(Constant)	57.633	5.551		10.383	0.000

Table 6.11: Multiple regression analysis.

However, the regression only explained around 29% of the variation in the dependent variable, other factors were having an impact. The three variables together do appear to explain a fair amount of the variation in the dependent variable, however, an even larger proportion is impacted by other variables. These other variables, that in fact do impact delivery reliability will be covered in the next chapter.

6.3 CONCLUSION

The analysis of the survey data produced some interesting results. The research examined the major factors that were considered by the plants to facilitate good delivery performance. The main factor considered by the plants was having a responsive planning and control system. The next most important factor was having a reliable supply chain.

The survey data was used to determine whether hypothesis H1 could be accepted. The hypothesis proposed that plants that manufactured a low proportion of customer products as customised products would have higher levels of delivery reliability than those plants that made a higher proportion. The results pointed to the fact that hypothesis H1 could be accepted. The results indicated that plants that produced a low level of customised products did in fact have higher levels of delivery reliability. On the other hand, those plants that produce a high proportion of customised products had a low level of delivery reliability.

The survey data was also used to determine if hypothesis H2 could be accepted. The hypothesis proposed that plants that manufactured complex products have low levels of delivery reliability. The results of the analysis indicate that the hypothesis was found not to hold. It would appear that part complexity does not impact delivery reliability. There may be several reasons why no relationship was found. Firstly, it may be that it is the process complexity that may have had a greater impact on delivery reliability and not part complexity. Secondly, the actual measure of part complexity used in the research may have been a poor measure of complexity. It may be possible that it did not measure the true level of complexity that was found in the manufacturing plant. This area still needs further investigation with an improved measure of part complexity.

The survey analysis found that plants that enjoyed high levels of supplier delivery reliability also achieved high levels of delivery reliability. The analysis also found that the level of demand uncertainty experienced by the plant management was related to the level of delivery reliability. There was a negative correlation between the two variables, so as the level of demand uncertainty increased, so the level of delivery reliability appeared to decline.

The survey analysis found that requirements (for delivery reliability) of the markets served by the plants did not appear to be related to the level of delivery reliability achieved by the plants. The plants that ranked delivery reliability as important were just as likely to have low levels of performance as the plants that ranked it as relatively unimportant. The results indicate that the importance to the customer of reliable delivery (as perceived by the plant's management) does not appear to be driving the actual delivery reliability achieved by the plant.

The analysis also found that where the customer had a major influence on the delivery date then delivery reliability was significantly better than in those plants where the influence was low or non-existent. It is likely that where the customer is having the most influence over the delivery date they are also expecting high levels of delivery reliability, which they receive. While those plants that they had greatest influence over setting delivery dates were actually achieving lower levels of delivery reliability.

The results of the multiple regression show that the main factors that are related to delivery reliability are the proportion of customised products, demanding customers, and supplier delivery reliability. The proportion of customised products is negatively related to delivery reliability. While the impact of demanding customers, and supplier delivery reliability is positively related to delivery reliability performance. However, the regression equation could only explain 29% of the variation in the delivery reliability. The implication of this is that other variables that were not being picked up in the survey were having an impact. The case study analysis, presented in the next chapter, will outline the other possible reasons for poor delivery reliability.

CHAPTER SEVEN

CASE STUDY ANALYSIS

7.0 INTRODUCTION

Chapter Seven presents the results of the analysis of the eight plants that were visited during the case study stage of the research. It starts with a brief description about how the eight plants were selected and the industry sector they came from. It then goes on to briefly give some background information about each of the plants, such as which individuals were interviewed, the type of product manufactured and the plant parent.

The main part of the chapter presents a cross case comparison of the case studies. Cross case comparisons of a number of areas are presented, in particular the delivery date quotation processes examined, as well as the focus of the management.

The final part of the chapter examines the four propositions that were first presented in Chapter Four of this thesis and evaluates, in the light of the case study analysis, if the propositions could be accepted or rejected.

7.1 THE SELECTION OF THE PLANTS

Eight plants were selected to form the core of the cases study phase of the research. The plants were selected from the companies that completed the Best Factory Awards survey questionnaire. This selection approach was used because the questionnaire that each plant completed (as part of the process of taking part in the awards) contained information about its delivery reliability and other variables that were important to the case study selection and pairing process. It was also decided to examine more than one individual sector - to be able to make meaningful statements about more than one

industry sector. The plants were taken from two industry sectors: electronics and engineering

The eight plants were grouped into pairs: two pairs of plants came from each of the two industry sectors. Since the management of the plants had completed a very detailed questionnaire it was possible to use the information and match the plants (into pairs). In each pair, one plant had low levels of delivery reliability and the other had high levels of delivery reliability. The selection was carried out to ensure that the plants were, as far as possible, similar on four potentially influential variables. This procedure was undertaken to ensure that the difference in the delivery reliability of the two plants (in a pair) could not be attributed to the fact that they were different on these key variables. For example, it may be possible to explain the difference in the delivery reliability of two plants purely on the basis of the fact that the plant with high levels of delivery reliability makes simple products, while the plant with low delivery reliability makes very complex products. The difference in complexity could possibly outweigh, for example, the impact of the performance measurement system. The variables that were controlled for were as follows:

1. Level of product complexity - the no of different components in the major product produced by the plant
2. The mix of make-to-order and make-for-stock
3. Proportion of products that are customised, unique, one-off products
4. The general size of the plant - number of employees

It proved difficult to exactly match the pair of plants on all the variables, however a degree of similarity was obtained for the 4 pairs; the reality of the situation is that no two plants are ever exactly the same. Each pair was matched on these four variables such that the differences (for these four variables) were minimised, the only real major difference between each plant, was the level of delivery reliability.

Using the case studies it was possible to examine the four propositions:

P1. In plants where the production planning department determines the delivery quotation, the level of delivery reliability will be high.

P2. In plants where the customers have expectations of high levels of delivery reliability, the level of delivery reliability will be high

P3. In plants where the management team is predominantly focused on delivery reliability, the level of delivery reliability will be high.

P4. In those plants where the performance measurement system has delivery reliability as a key area of focus, levels of delivery reliability will be high.

For each case study a number of areas were examined. The areas examined were as follows:

- Delivery date quotation - which department was responsible and the approach used to arrive at the delivery date
- Customers - who the customers were and how demanding they were
- Production planning - who was responsible for the development of the master production schedule
- Management focus - the degree of focus of the plant management on delivery reliability
- Performance measurement - the focus of the performance measures used in the plant

7.2 THE PLANTS

Table 7.1 shows the delivery reliability of each of the plants and the delivery reliability group they belong too. The table shows the plants in their pairs, so for example ENGAHIGH and ENGALOW were a pair of engineering plants (with ENGAHIGH having high levels of delivery reliability).

Sector	Plant	Delivery Reliability	Delivery Reliability Group
Engineering	ENGAHIGH	100%	High group
Engineering	ENGALOW	92%	Low group
Engineering	ENGBHIGH	98%	High group
Engineering	ENGBLOW	90%	Low group
Electronics	ELAHIGH	100%	High group
Electronics	ELALOW	91%	Low group
Electronics	ELBHIGH	100%	High group
Electronics	ELBLOW	75%	Low group

Table 7.1: Delivery reliability for the 8 plants.

For the purpose of cross case analysis that will be presented in this chapter, the plants have been placed into one of two groups:

1. High delivery reliability
2. Low delivery reliability

Table 7.1 indicates which delivery reliability each plant falls into, for example ENGAHIGH is an engineering plant that is in the high delivery reliability group. While ENGALOW is an engineering plant that is in the low delivery reliability group. Table 7.2 outlines the products the 8 plants manufactured.

Sector	Plant	Product
Engineering	ENGAHIGH	Car component manufacture
Engineering	ENGALOW	Spring manufacturer
Engineering	ENGBHIGH	Hydraulic valves
Engineering	ENGBLOW	Hydraulic valves
Electronics	ELAHIGH	Electronics equipment
Electronics	ELALOW	Electronics equipment
Electronics	ELBHIGH	Telecommunications equipment
Electronics	ELBLOW	Telecommunications equipment

Table 7.2: The products manufactured by the 8 plants.

The next part of this section provides some background information about each of the plants along with information about the individuals who were interviewed at each of the plants.

7.2.1 Plant ENGAHIGH

Plant ENGAHIGH manufactured car interior components that were shipped directly its customers - car assembly plants. The plant was a first tier supplier to a number of car manufacturers in the UK and Europe, and was part of a large Japanese manufacturing company. Around 500 production related employees (direct and indirect) employed at the plant.

The plant had a number of production areas: press shop, injection moulding, heat treatment and plating, and final assembly cells. The production of the product started with metal parts being punched and formed in the press shop, these were then heat treated and plated. Plastic components were manufactured in the injection moulding area. Finally all the components, including those obtained from external suppliers, were assembled together to make the final product in the assembly cells. The final assembly area contained a number of assembly cells (u-shaped), each cell was dedicated to a particular customer.

The products manufactured at the plant were customer specific, with each customer receiving regular deliveries (every two days or weekly) from the plant. The plant supplied all its customers on a make-to-order basis.

A number of managers who were based at the plant were interviewed:

Managing Director
Production Manager (Fabrication)
Materials Manager
Senior Buyer

The Managing Director had overall responsibility for the plant and he had two production managers reporting to him. One manager covered the assembly operation and the other (the production manager interviewed) looked after the press shop, plating and injection moulding - collectively known as "fabrication". At the time of the interviews, the Materials Manager was temporarily responsible for the assembly operation as well as the production planning and control. He was temporarily responsible for the assembly operation, pending the appointment of a new Production Manager. The Production Manager (fabrication), and the Materials Manager reported directly to the Managing Director, while the Senior Buyer reported to the Purchasing Director, who in turn reported to the Managing Director.

7.2.2 Plant ENGALOW

Plant ENGALOW manufactured springs and spring assemblies, these were used by other manufacturers in their final product. The plant was owned by a large European manufacturer and the plant employed around 200 production related employees.

The plant had three major production areas: press shop, high volume assembly area and a low volume assembly area. The manufacturing process started with the cutting of steel coils into the appropriate lengths, these coils were then passed to one of the two production areas: high volume product area or the low volume area. The high volume area assembled the springs into the appropriate mounting fixtures. The low volume area assembled the springs into the appropriate assemblies requested by the customer. This side of the operation processed very small order quantities. The high volume area supplied around 30 customers, while the low volume area supplied several hundred customers. The plant supplied the overwhelming majority (90%) of its customers on a make to order basis, and only 10% of output was supplied off the shelf.

The following managers were interviewed at the plant:

Production Director
Production Controller
Sales and Marketing Manager
Purchasing Manager

The Production Manager had overall responsibility for the plant and reported to the company General Manager. The Production Controller reported to the Production Director. All the other individuals interviewed, reported to the General Manager

7.2.3 Plant ENGBHIGH

Plant ENGBHIGH manufactured hydraulic values that were shipped to customers across Europe and the United States of America. The plant employed around 150 production related employees (direct and indirect) and was part of a large diversified Japanese manufacturer. The plant mainly manufactured a range of standard products (70%), however it also manufactured some customer specific products. A large

proportion (80%) of its output was manufactured on a make-to-order basis, with the remainder supplied off the shelf.

The main production areas in the plant were: component manufacture, final assembly, test and paint. The production of the product started with the manufacture of the various components, these were then passed to the assembly area where they were assembled. The final stage of production involved testing the assembled products, once this had been completed, they were painted and then boxed ready for despatch to the customer.

The following individuals at the plant were interviewed:

General Manager
Commercial Manager
Operations Manager
Production Controller
Purchasing Manager

The General Manager was responsible for manufacturing and also the commercial operations. The Operations Manager was responsible for the plant and its operation; the Production Controller and the Purchasing Manager both reported to the Operations Manager. The Commercial Manager looked after the sales and marketing of the product manufactured by the plant; the Commercial Manager reported to the General Manager.

7.2.4 Plant ENGBLOW

Plant ENGBLOW manufactured a series of hydraulic valves, which it supplied to a few key customers in the UK. The plant employed around 140 production related employees (direct and indirect) and was part of a UK manufacturing organisation.

The plant manufactured a range of customer specific products on a repeat order basis (75%), although it did manufacture some unique customised products. The plant supplied all its products on a make-to-order basis.

The main production areas in the plant were component manufacture, final assembly and test. The production of the product started with the manufacture of various components, these were then brought together in assembly. The assembled product was then passed to the test area and then despatched to the customer.

In the case of plant ENGBLOW the following individuals were interviewed:

General Manager
Production Manager
Production Planning Manager
Purchasing Manager

The General Manager was responsible for all the plants' operations, the Production Manager, Production Planning Manager and the Purchasing Manager all reported to him.

7.2.5 Plant ELAHIGH

Plant ELAHIGH employed 573 production related employees (direct and indirect) and was part of a large Japanese organisation. The plant manufactured a range of customer specific products. The plant manufactured a range of customer specific products to repeat order (95%), however it did a small proportion (5%) of unique customised products. The plant contained a number of printed circuit board assembly lines, most of which were dedicated to a specific customer - on average one assembly line per customer.

The following individuals were interviewed:

General Manager
Operations Manager
Planning Manager
Purchasing Manager

At plant ELAHIGH the General Manager was responsible for both the manufacturing and sales operations of the plant. The Operations Manager (interviewed) was responsible for one of the assembly lines (usually one specific customer). The plant had organised its personnel around customers, each customer had a dedicated production line. Each Operations Manager had a team of people reporting to him, the team included a Planning Manager, Materials Manager, and Quality Engineer. Material procurement was carried out by a central department and the Purchasing Manager (who was interviewed) reported to the General Manager.

7.2.6 Plant ELALOW

Plant ELALOW employed 437 production related employees (direct and indirect) and was part of a large North American organisation. The production of the product started with the printed circuit board assembly, the completed boards were then tested and then passed to the assembly cells where the final product was assembled. After which a final sample test operation was undertaken.

In the case of plant ELALOW the following individuals were interviewed:

Plant Director
Manufacturing Manager
Planning Manager
Purchasing Manager

Marketing Manager

At plant ELALOW the Plant Director was responsible for the total plant operations, all the managers interviewed except the Marketing Manager reported to the Plant Director. The Marketing Manager was based at another location and reported to the Marketing Director.

7.2.7 Plant ELBHIGH

Plant ELBHIGH employed around 450 production employees (direct and indirect) and was part of a large manufacturing operation with a European parent. The plant manufactured telecommunications equipment. The product was manufactured to the customers' specific requirements, and supplied on an on-going basis. The manufacturing site supplied products to customers across Europe.

The main production areas in the plant were: printed circuit board assembly, cable manufacture, cabinet assembly, final assembly and test. The production of the telecommunications of the telecommunications products started with the manufacture of the printed circuit boards. At the same time the cables that connect the boards together in the final product were manufactured. All the items that made up the final product were then brought together, assembled and tested. From the test area the product moved to the despatch area, where it was packed, ready for despatch to the customer.

A number of managers who were based at plant ELBHIGH were interviewed. The individuals interviewed were as follows:

Logistics Manager
Manufacturing Manager
Materials Planning Manager
Purchasing Manager

Order Planning Manager

In plant ELBHIGH, the Logistics Manager was responsible for the processing of customer orders, production planning and materials management. All the managers interviewed except for the Manufacturing Manager reported to the Logistics Manager. Both the Logistics Manager and the Manufacturing Manager (who was interviewed) reported to the Production Director. The Manufacturing Manager was responsible for the operation of the plant. However, his department was expected to take its lead from the Logistics department (which the Logistics Manager managed).

7.2.8 Plant ELBLOW

Plant ELBLOW was part of a large UK company, with various plants located in Britain, around 630 production employees were employed at the plant. Plant ELBLOW manufactured a standard range of telecommunications equipment and its products were shipped to customers across Europe.

The main production areas in the plant were: printed circuit board assembly, cable manufacture, cabinet assembly, final assembly and test. Production started with the manufacture of the printed circuit boards, then the cabinets that held the boards were manufactured, along with the cables that connected up the boards. The boards were fitted into the cabinets and then connected together and tested. Once the final test had been completed the product was moved to the despatch area for packing.

In the case of plant ELBLOW the following individuals were interviewed:

Plant Manager
Production Manager
Materials Manager
Purchasing Manager

Business Planning Manager

The Plant Manager had overall responsibility for the plant and all the individuals interviewed, except for the Business Planning Manager, reported to him. The Business Planning Manager was located at another site and was responsible for the marketing of the product range that the plant manufactured.

Having reviewed the eight case study plants let us now examine a number of areas that were explored during the case studies.

7.3 DELIVERY DATE QUOTATION

Several writers (Tatsiopoulos & Kingsman, 1983; New & Sweeney, 1984) have indicated the importance (for the make-to-order manufacturing company) of the delivery date quotation activity. One element of the case study research involved identifying the department primarily responsible for delivery due date quotations, and understanding how the delivery due date quotation process was undertaken.

A number of managers at each plant were asked about the delivery date quotation process. Table 7.3 outlines which department was responsible for developing the delivery date quotation at each of the 8 plants[1]. At a number of the plants the Sales department supplied the customer with the quotation, however what Table 7.3 shows is the department that was actually developing the delivery quotation. In Table 7.3 the plants have been separated into two groups, with the high delivery group (ENGAHIGH, ENGBHIGH, ELAHIGH and ELBHIGH) appearing at the top and those in the low group (ENGALOW, ENGBLOW, ELALOW and ELBLOW) at the bottom of the table.

Plant	Quotation developed by	Quotation based on	Production involved	Additional comments
ENGA HIGH	Planning Department	Manufacturing lead times Load and capacity	Yes	
ENGB HIGH	Sales Department Production Planning	Manufacturing lead times Load and capacity	Yes	
ELA HIGH	Production Planning	Manufacturing lead times Load and capacity	Yes	
ELB HIGH	Materials Planning	Manufacturing lead times Load and capacity	Yes	Order Planning also involved
ENGA LOW	Customer Support Department	Standard lead times	Only for high volume orders	For large high volume orders Production and Planning determine the quotation
ENGB LOW	Production Planning	Standard lead times. For customer specials manufacturing lead times determined	No	
ELA LOW	Production Planning	Manufacturing lead times Load and capacity	No	Marketing has sometimes supplied quotations without consulting the Plant.
ELB LOW	Logistics Department	Standard lead times	No	Logistics Department is not located at the plant.

Table 7.3: Departments responsible for delivery date quotations.

At all four plants in the high group, the Production Planning department (or Materials Planning as it was called at ELBHIGH) was involved in the process of developing the delivery date quotations. In the case of ENGBHIGH the Sales department was also

[1] Please note that the majority of the tables presented in this chapter are based on the results from more than one interview at each plant.

involved in the process, however this is slightly misleading because the plant used a cyclical approach to production (4 week cycles). The reality was that the Planning department had specified how many items of a particular product it was possible to manufacture per day. If the Sales department received an order for more than the daily quantity, they would have to consult Planning. They decided whether the order could be made in the appropriate production week, or if the order needed to be split, with part of it being manufactured in the current period and the remainder manufactured the next time the product was being made (that is in the next cycle). Sales also had to consult Planning in the case of customised products (unique customer specific products) in such a case the Planning department would determine the delivery date:

"We [Sales Department] talk to planning, who then give us the quote" (Commercial Manager)

The managers at ENGBHIGH had placed a lot of emphasis on ensuring that the due date quoted was accurate:

"We have spent a lot of time explaining the importance of offering an accurate delivery date" (Commercial Manager).

This policy seemed to be effective in ensuring that the factory was not overloaded by the Sales department:

"Sales are very good in following the procedures, they don't attempt to take more orders in a week than allowed" (Operations Manager).

In the case of the low delivery group Table 7.3 shows that, unlike in the high group, various departments were involved in developing the quotation. The Production Planning department was not always involved in providing the quotation.

At plant ENGALOW, the Sales department was responsible for providing the quotation, while at ELBLOW the Logistics department (located at another site) was responsible for providing the quotation. However, in the case of the other two plants the Production Planning department was involved. Plants ENGBLOW and ELALOW followed the same approach as that used by the high group of plants. ENGBLOW and ELALOW both used the Production Planning department to determine the delivery date. However, in the case of ELALOW, although the Planning department was supposed to provide the quotation there had been a number of instances where the company's Marketing department had provided a quotation independently, without consulting the Planning department.

"We have had problems with Marketing in the past when they committed us to dates, before consulting with us" (Manufacturing Manager Plant ELALOW).

This fact was backed up by what the Marketing Manager said during the course of the interview:

"Sometimes commercial pressures force you to take a calculated risk, the customer needs a date now ... you can usually make a good estimate of the delivery date" (Marketing Manager).

New and Myers (1986) make the point that to ensure that realistic delivery dates are quoted the Production Planning department should be responsible for determining the delivery quotation. Plants where the Production Planning department is responsible for developing the delivery date quotation are able to ensure that realistic quotations are developed. Plants where another department is responsible for developing the quotation may find that unrealistic dates have been quoted. If other departments are responsible for providing the delivery date quotation there is a danger of over-committing capacity. Table 7.3 indicates that at all plants in the high delivery group, the Production Planning department was responsible for providing the delivery date

quotation. However, in the low group, at only two of the plants (ENGBLOW and ELALOW) was the Production Planning department responsible for the quotation of delivery dates. And, in the case of ELALOW the Marketing department had supplied customers with delivery quotations without consulting the Production Planning department. The results of the analysis indicate that, on the whole, plants where the Production Planning department is responsible for the delivery date quotation the plants are likely to achieve high levels of delivery reliability.

Which department arrives at the due date quotation is only part of the equation, probably more important is the approach used to arrive at the quotation. Although Production Planning has a far greater idea than the Sales department how long it takes to manufacture a particular product, knowing the actual manufacturing lead time is only one piece of the information required in order to arrive at a realistic delivery due date. At each of the plants an investigation was carried out into how the delivery date quotation was determined. Table 7.4 shows the different methods used to arrive at a quotation by the 8 plants.

From Table 7.4 we can see that all the plants in the high group developed their quotation taking into account the load and capacity of the plant, as well as calculating the manufacturing lead times. In the low group the situation was different, three of the plants based their quotations on standard lead times, only plant ELALOW developed the delivery quotation determined by taking into account load and capacity when determining delivery due dates. However, as I have already mentioned, the plant suffered from the problem that the Production Planning Department did not always provide the quotation. The plant's Marketing Department had in the past offered customers' delivery date quotations without checking with the Production Planning Department and thereby committing the plant to delivery dates that were not achievable.

High Group	Low Group
ENGAHIGH: Manufacturing lead times Load and capacity	ENGALOW: Standard lead times
ENGBHIGH: Manufacturing lead times Load and capacity	ENGBLOW: Standard lead times. For customer specials manufacturing lead times calculated
ELAHIGH: Manufacturing lead times Load and capacity	ELALOW: Manufacturing lead times Load and capacity
ELBHIGH Manufacturing lead times Load and capacity	ELBLOW: Standard lead times

Table 7.4: The method used to arrive at delivery quotations.

The use of standard lead times by the low group, to develop the delivery quotation, while very simple to use, does ignore some vital elements that can have an impact on the actual lead time in the plant. Many writers (New, 1977) (Hendry & Kingsman, 1989) in the field have pointed to the fact that in order to arrive at realistic delivery date it is important to take account of the load and capacity of the manufacturing operation. It is possible to estimate the total manufacturing lead time (how long it takes to make the product) by building it up from operation times, set-up times, move times etc., but this will only produce part of the picture. The use of standard lead times (based on manufacturing lead times) does not allow for the determination of a realistic lead time because it ignores the impact that the other orders in the factory will have on the actual lead time (of the order). Also, it ignores the plant capacity and the impact this has on the lead time of the order. The estimation of a realistic delivery date requires knowledge of the load placed on the plant, the capacity available and any other outstanding commitments.

Quoting delivery dates based on standard lead times will result in the plant not being able to meet all its delivery promises if the plant becomes overloaded and capacity

cannot be expanded. By quoting standard lead times, the plants in the low group left themselves with little room for manoeuvre when they became overloaded and they had no spare capacity. However, if they had not quoted standard lead times they would have been able to quote longer lead times, if they felt that the plant would be overloaded and capacity could not be expanded.

To conclude, the examination of the process of delivery date quotation reveals that there was a difference between those plants that achieved high levels of delivery reliability and those that had low levels. At plants with high levels of delivery reliability, the delivery quotation was developed by the Production Planning department. Also, the process of delivery date quotation involved taking into account the manufacturing lead times, the current and future load and capacity. However, at the plants with low levels of delivery reliability the approach was different. In a majority of the plants (in the low group) the delivery quotation was based on standard lead times and for some plants the quotation was developed by other departments and not the Production Planning department. The only plant, in the low group, which quoted delivery dates based on the load and capacity (and where the quotation was developed by the Production Planning department) was handicapped by the fact that some of the quotations were produced by the Marketing department who did not consult the Production Planning Department. The end result of this action would have resulted in unrealistic delivery quotations.

7.4 THE CUSTOMER

One of the areas that was explored as part of the case study research was the subject of customers. Table 7.5 shows the number of customers each plant supplied. The 8 plants supplied varying numbers of customers, with plant ENGBLOW supplying the smallest number (only 5), and plant ENGALOW supplying the largest number of customers - 1047., and from the table we can see that there is no discernible difference between the two groups of plants.

Plant	No of Customers	Type of Customer	Product Type
ENGAHIGH	10	Manufacturer - cars	Customer specific to repeat order
ENGBHIGH	117	Distributors	Standard product
ELAHIGH	7	Manufacturers - final product	Customer specific to repeat order
ELBHIGH	10	Telecomms supplier	Customer specific to repeat order
ENGALOW	1047	Manufacturer - final product	Standard & customer specific
ENGBLOW	5	Manufacturer - sub assemblies	Customer specific to repeat order
ELALOW	10	Telecomms supplier	Customer specific to repeat order
ELBLOW	200	Telecomms supplier	Standard product

Table 7.5: Plant customers.

Table 7.5 also shows the type of product manufactured by each plant: standard product or customer specific products manufactured to repeat order. From Table 7.5 we can see that 3 out of the 4 plants in the high group manufactured customer specific products to repeat order and only one manufactured standard products. In the low group only one plant manufactured standard products (plant ELBLOW), and one plant (ENGALOW) made a mix of standard and customer specific products. The two remaining plants, ENGBLOW and ELALOW, manufactured customer specific products to repeat order.

Table 7.5 indicates that just because a plant manufactures standard products, this is no guarantee that it will achieve high levels of delivery reliability. Plant ENGBHIGH manufactured standard products and also achieved high levels of delivery reliability, however while plant ELBLOW also manufactured standard products, it did not enjoy the same levels of high delivery reliability.

In the high group, ENGAHIGH and ENGBHIGH utilised customer focused cells in their final assembly operations, which allowed them to manage the task of making customer specific products more easily.

Table 7.5 also shows the general type of customers that each plant supplied, these differed within the two groups of plants. There was a mix of manufactures and distributors/retailers of the final product in each of the two groups. Among the high group, plant ENGAHIGH supplied car manufacturers, plant ELAHIGH supplied components for the manufacture of the final product, while plant ENGBHIGH supplied the final product to distributors, and plant ELBHIGH also supplied a final product to telecommunications suppliers. In the low group there was again a mix of customer types, plant ENGALOW supplied manufacturers where the product formed a part of the final product. Plant ENGBLOW also supplied sub assembly manufactures. Plant ELALOW and ELBLOW supplied their final products to several telecommunications suppliers.

Having examined who the customers were, let us now examine the issue of just how demanding the customers were in terms of the delivery reliability they received from the plants.

7.5 CUSTOMER DEMANDS

One of the possible reasons, behind the difference between the delivery reliability of the two groups, was the importance that the market placed on delivery reliability. It

could be that the plants in the high group operated in markets where delivery reliability was much more important than price or product features. The level of relative importance (based on customer perceptions) that the market attached to five criteria, was obtained from the plant management, the five criteria were:

- Quoted delivery lead times
- Reliability of delivery date
- Product features
- Level of product customisation
- Price

Table 7.6 presents the top three criteria in order of importance, for each plant.

Plant	**Market criteria (ranked)**		
ENGAHIGH	1. Product features	2. Level of customisation	3. Delivery reliability
ENGBHIGH	1. Delivery reliability	2. Lead times	3. Price
ELAHIGH	1. Price	2. Delivery reliability	3. Lead times
ELBHIGH	1. Price	2. Product features	3. Lead times
ENGALOW	1. Delivery reliability	2. Price	3. Level of customisation
ENGBLOW	1. Price	2. Delivery reliability	3. Lead times
ELALOW	1. Delivery reliability	2. Price	3. Lead times
ELBLOW	1. Price	2. Product features	3. Delivery reliability

Table 7.6: Top three market criteria for each plant.

Surprisingly, for 3 out of the 4 plants in the high performing group, the main market criterion was not delivery reliability, for 2 of the 3 plants (ENGAHIGH and ELBHIGH) it is much lower down the list. In the low group we find that for two of the plants (ENGALOW and ELALOW) delivery reliability is very important and yet the plants were not achieving high levels of delivery reliability. From the table it would appear, that just because the market is perceived to value a high level of

delivery reliability, it does not mean that the plants will deliver the required level of performance there was another force at work - demanding customers.

Table 7.7 shows the degree to which each plant's customer was demanding. One area where a significant difference existed between the low and high groups was the degree to which the plants' customers were demanding with regard to on-time delivery reliability. In the case of the high group all four plants reported having very demanding customers when it came to delivery reliability.

Plant	Customers	Relationship	Product destination
ENGAHIGH	Demanding customers - expect on-time delivery	Close - continuous contact customer feedback	To point of use
ENGBHIGH	Demanding customers - expect on-time delivery	Close - has view of some of its customer stock levels	Warehouse, in some cases to installation point
ELAHIGH	Demanding customers - a number of customers monitor the plant on delivery reliability	Close - continuous contact customer monitoring and feedback	Point of use
ELBHIGH	Demanding customers - expect on-time delivery	Close - continuous contact	Point of use, ready for installation
ENGALOW	High volume customers demanding The other customers not particularly demanding	Close for high volume products	Point of use, manufacturers stores
ENGBLOW	Main customer demanding because of continuously changing requirements	Close contact	Manufacturer stores, if urgent then to point of use
ELALOW	Not particularly demanding, will accept late delivery	Not close, Sales and Marketing deal with customer	Warehouse
ELBLOW	Major customer demanding, the rest are less demanding	Not close, Marketing deals with customer	Warehouse

Table 7.7: Customers and relationships.

The customers that plant ENGAHIGH supplied were very demanding with regard to delivery, even partial shipments to the customer were not looked on favourably. There was a lot of pressure to deliver on time, as the Materials Manager commented:

"We do everything we can to avoid short shipment"

This fact was confirmed by the Production Manager:

"You don't deliver late..... if you do miss a shipment, you air freight" (Production Manager).

The Materials Manager pointed to the penalty that was suffered if the plant delivered late:

"If we stop a line [customer production line] it is big money involved"

In the case of ENGBHIGH, their customers also expect good delivery

"The customer expects good delivery from us" (General Manager).

The Commercial Manager indicated during the interviews that the plant had pursued a policy in the past of providing its customers with good delivery reliability. And since the plant had been achieving high levels of delivery reliability in the past, their customers had begun to expect it as part of the service.

Plant ELAHIGH customers were also demanding, because the plant manufactured a key component of its customer final product so delays in the shipment of the component would in effect stop the customer's production line:

"they operate with short lead times ... [and] they don't hold large buffer stocks .. they need us to deliver on time" (Operations Manager)

The demands of the customer meant that the plant had to deliver on time consistently to do anything else could not have been considered:

"Quality and delivery are expected to be there [by the customer], it is just assumed to be good" (General Manager).

Another indication of just how important on-time delivery was to plant ELAHIGH customers was the fact that its major customers monitored the plant's delivery reliability and they discussed the performance (alongside price and quality) on a quarterly basis with the plant's management.

Plant ELBHIGH manufactured a key piece of telecommunications equipment that the customer expected to be used by a certain date and so expect it to be delivered on-time:

"We are shipping to network sites ... the customer expects these sites to be operational by a certain date and so we need to deliver the product on-time so that it can be installed .. we cannot be late in delivering because that may jeopardise the site being operational by the planned date" (Logistics Manager)

The Order Planning Manager also made the comment:

"The customer tends to expect good delivery performance .. being late can impact your future business with them" (Order Planning Manager).

In the case of the low group, the situation was slightly different, not all the customers were demanding to the same degree and so the plants could deliver late to some

without this fact having a detrimental impact. Plants ENGALOW, ENGBLOW and ELBLOW had a mix of demanding and undemanding customers. In the case of ENGALOW, some of the customers they supplied on a regular basis (the high volume customers) were demanding:

"on the high side [high volume customers] it is mandatory for us to deliver on time" (Sales & Marketing Manager)

The remaining customers were not as demanding and so they received lower levels of delivery reliability, the Sales and Marketing Manager added that on the low volume side their customers gave them a lot of leeway to be late. The Production Director at ENGALOW was also of the opinion that most customers were prepared to accept late delivery of their order:

"So long as we tell them if there is a problem that is okay, they are prepared to accept a delay ...if we can tell them when the product will be with them they will be happy" (Production Director).

In the case of plant ENGBLOW, their main customer was demanding, expecting the plant to react to his urgent requirements:

"If you are late in delivering to them you get no end of phone calls and faxes, where are the parts, when will they get here .. your making us late on our contract" (Production Planning Manager).

However, the other customers were not as demanding being prepared to accept late delivery.

Plant ELBLOW supplied their major customer fairly consistently on-time (the Materials Manager had said to me that their major customer had enjoy 'on-time

delivery' for the past six months). However, their delivery reliability to the rest was much worse. The minor customers were the ones who received poor delivery, but they also appeared to be prepared to accept late delivery from the plant:

"If we can tell them when we can deliver, most of them will be prepared to accept the delay" (Plant Manager)

This view was backed up by the comments made by the Material Manager:

"If we go back and tell the customer sorry but we're going to be late on this order by a couple of days, usually that okay" (Material Manager).

Plant ELALOW appeared to have the least demanding customers of all the plants. ELALOW customers appeared to accept late delivery, a comment made by the Marketing Manager indicated that dates were changed and new ones agreed by the customer:

"If we are going to be late we will go to them and agree a new shipment date" (Marketing Manager)

The Planning Manager also echoed this view:

"Most of our customers are prepared to accept a new shipment date" (Planning Manager).

The plants in the low group were able to manage customer order priorities, the customers who were the most important or the least prepared to accept a delay, received priority over everybody else. In the high group the plant management could not do this, they had to please everybody and so they managed their operations to ensure that all their customers' delivery date requirements were met.

Another area where there appeared to be differences was the type of relationship that the plant had with its customers. All the high performing plants had a much closer relationship with their customers, than most of the plants in the low group. This relationship had arisen in the case of two of the plants (ENGAHIGH and ELAHIGH) because they were having to supply their customers regularly - on a just-in-time basis. The fact that they supplied their customers daily or on a weekly basis, meant that they had to be in regular contact in order to know what the current and future requirements were. The regular supply meant that the plants also received regular updates of future forecast requirements that allowed them to plan future production more effectively, especially the likely level of capacity required. Plants ENGAHIGH, ELAHIGH and ELBHIGH all received forecast of future requirements on a regular basis from their major customers.

In the case of plant ELBHIGH, the plant shipped its products to installation sites and so it needed to be in constant contact to determine if the installation date had been put back. Plant ENGBHIGH maintained close contact with most of its major distributors, the customer service operation frequently checked the stock levels of its major distributors, especially in the USA. This close contact with its customers arose out of a historical desire not to be surprised by sudden increases in order levels, which they had not fulfilled in the past.

The type of relationship (with their customers) that the plants in the low group had was not particularly close. Both plants, ELALOW and ELBLOW, did not have a lot of direct contact with their customers. The contact that did take place was undertaken by the Sales and Marketing departments, and these departments were physically separate from the plants. The remaining two plants (ENGALOW and ENGBLOW) in the low group, did have a greater degree of contact with their customers. Plant ENGALOW maintained fairly close contact with some of its customers. This was due to the fact, that like plants ENGAHIGH and ELAHIGH, it was supplying these

customers on a regular basis and so needed to maintain close contacts. The plant received information about forecast requirements. However, the close relationship did not extend to its other customers - the low volume customers. Plant ENGBLOW also supplies it customer on a regular basis and so also had a close relationship with them. The majority of its customers supplied it with forward forecast requirements however in the view of the Production Planning Manager these forecasts were not particularly reliable and were prone to changes.

In conclusion the analysis points to one major difference between the two groups of plants - demanding customers. The majority of the plants in the high group supplied mainly demanding customers. These customers expected on-time delivery consistently - for two of the plants poor delivery reliability would have a detrimental impact on future business. These customers expected high levels of delivery reliability and so they received it.

In the low group the situation was slightly different - the customers tended to fall into two groups, demanding or undemanding. For these plants, some of their customers were demanding, however the rest of the customers were not demanding and appeared to accept late delivery. This difference between the two groups of customers means that the undemanding customer orders would receive a lower priority in the manufacturing plant. If the plant management had to make order priority decisions then the demanding customers' orders would move ahead of the undemanding customers' orders (which had a lower priority). The demanding customers' orders would be more likely to be completed on time when compared to the undemanding customers' orders. So, the demanding customers would receive high levels of delivery reliability, while the less demanding would receive lower levels of delivery reliability.

7.6 PRODUCTION PLANNING

One of the areas that was explored as part of the case study research was the process of production planning. An important element in the production planning process is the development of the master production schedule (MPS): which is a statement of what, when and how much is to be manufactured (Plossl & Welch, 1979). Table 7.8 displays who was responsible for the development of the master production schedule at each of the plants and also which individuals, in the plant, agreed the schedule.

Plant	MPS Developed	Horizon	Developed by:	Approved by:
ENGAHIGH	Monthly.	6 months	Materials Manager.	General Manager, Production Managers.
ENGBHIGH	Monthly.	6 months	Production controller.	General Manager, Operations Manager and Commercial Manager.
ELAHIGH	Monthly.	3 months	Master Production Scheduler.	General manager and Operation Managers.
ELBHIGH	Monthly.	12 months	Materials Planning Manager.	Manufacturing Manager, Order Planning Manager and the Logistics Manager.
ENGALOW	Monthly.	6 months	Production Controller.	Production Director.
ENGBLOW	Monthly.	12 months	Production Planning Manager.	General Manager
ELALOW	Monthly.	12 months	Planning manager.	Plant Director, Finance Director and Manufacturing Manager.
ELBLOW	Monthly.	6 months	Materials Manager.	Plant Manager.

Table 7.8: Master Production Schedule.

In all the plants (both the high group and the low group) the MPS was produced on a monthly basis. The person responsible for developing the MPS, was either the

Production Planning Manager or the Materials Manager. Only plant ELAHIGH had a dedicated Master Production Scheduler responsible for developing the MPS. This presence, at ELAHIGH, of a person dedicated to the role, was due to the fact that the plant contained production cells that each undertook its own day to day planning. Consequently a person was required to provide an overall view of the plants total future requirements.

If we examine who agreed the final Master Production Schedule, we can see some difference between the two groups. In the high group, we can see that the Production department agreed the MPS. In the low group, we find Production approving the MPS at only two of the plants: ENGALOW and ELALOW. At plant ENGBLOW and ELBLOW only the General Manager and the Plant Manager, respectively, agreed the MPS.

An important element of good master production scheduling practice is the development of a realistic master schedule (Plossl, 1973). The MPS should state what the plant is and will be capable of making, and not what the managers would like to be making (Plossl, 1973). Any attempt to put more into the MPS than the plant is capable of producing will only result in poor delivery reliability, higher inventory and increased manufacturing cost (Orlicky, 1975). Also, if a plan is not achievable, the Production employees will loose faith in it, they will no longer believe future schedules and the informal system will take over (Plossl & Welch, 1979). The MPS does not belong exclusively to the Planning department, it may start life in the Planning department but it does not end there, it has to be implemented by the Production department. Therefore, it is important that the plan produced by the Planning Department is checked and approved by the appropriate managers in Production (Goddard, 1986).

In all the plants in the high group the Production department was involved in approving the MPS and so it was likely that the final MPS, as agreed, was realistic

and achievable. However, in two of the low plants (ENGBLOW and ELBLOW), Production was not involved in approving the MPS. Although the General Manager at ENGBLOW and the Plant Manager at ELBLOW approved the Master Schedule, it may be that these master schedules were a reflection of what they would like to be making rather than what they could realistically manufacture. As has already been pointed out, if the MPS is not realistic then the situation will arise that the plant will become overloaded and the plant will not be able to meet all the delivery due dates.

Another area of production planning that was explored as part of the research was the detailed production schedule/final assembly schedule. This schedule provided information about which products (and the quantity), were to be produced on a particular day (and on which production line if relevant).

Table 7.9, shows which individual produced the production schedule and also which individuals approved the final detailed schedule. In both the high group and the low group the schedule was developed by the Production Planner or the Materials Manager; Table 7.9 shows that there was no real difference between the two groups in terms of who developed the schedule. However, a difference did exist, when it comes to which individuals approved the detailed production schedule. In the high group, the Production Manager was involved in approving the detailed schedule.

However, in the case of the low group, we find that only at ENGALOW and ENGBLOW was the Production Manager involved in approving the detailed schedule. At plants ELALOW, and ELBLOW, the Plant Manager approved the schedule. As has been indicated earlier, it is not advisable to produce a plan without first ensuring it is achievable - Production can help in this task.

Plant	Production schedule	Variability
ENGAHIGH	Developed by the Materials Manager. Approved by the General Manager and Production Managers.	None - fixed for a week.
ENGBHIGH	Developed by Production Controller. Approved by the Commercial Manager and the Operations Manager	None - fixed for a four week period
ELAHIGH	Developed by Planning Manager. Approved by the Operations Manager	Supposed to be fixed for the week, but can change slightly over the week.
ELBHIGH	Developed by the Materials Manager. Approved by the Manufacturing Manager	None - fixed for the month (but changes possible at the end of the month[2]).
ENGALOW	Developed by production controller. Approved by production and customer support department.	None - fixed for the week (but some changes are made).
ENGBLOW	Developed by the production planning manager. Approved by the Production manager	Some - changes over the month
ELALOW	Developed by Production Planner Approved by the Plant Manager	Some - changes over the month
ELBLOW	Developed by Materials Manager. Approved by the Plant Manager	Some - changes over the month

Table 7.9: Production schedule.

Table 7.9, also shows another major difference between the two groups of plants and that is in the degree of variability in the production schedule. The majority of the plants in the high group did not have a very fluctuating schedule, once the production schedule had been agreed, it tended to be fixed for the short term. ELBHIGH in theory had a fixed schedule for the month, they could make changes towards the end of the month, but not particularly dramatic changes. However, they tried to avoid making changes because of the disruption they could cause them.

[2] Some changes are possible towards the end of the month, but not dramatic ones. However, they try to avoid making changes due to the disruption it can cause.

At plant ELAHIGH the intention was to have a fixed plan for the week, however, the reality is that it did change:

"In theory you have a fixed element, the reality is that you have to flex" (Operations Manager.

The Planning Manager commented on the situation:

"We want to have a stable plan for the week, we expect the customer not to change their requirements; but a lot of them do and we respond to that" (Planning Manager).

In the case of plant ENGAHIGH although the weekly schedule was fixed there was some variation between what the customer initially required and what they actually ordered during the month.

In the low group for three of the four plants (ENGBLOW, ELALOW and ELBLOW) the schedule was not fixed. In three plants the actual production schedule varied from the initial schedule that was agreed. Plants ENGBLOW and ELALOW suffered from the problem of customers changing their requirements at the last minute.

The Production Planning Manager at ENGBLOW stated:

"our customers force us into a lot of reschedules" (Production Planning Manager)

The Manufacturing Manager at ELALOW stated:

"The schedule does change as the week goes on .. Why? Because the customer changes his mind, materials stock out - the plastic supply has been a problem for the last two months" (Manufacturing Manager)

Plant ELBLOW experienced the problem of self imposed changes because customer due dates were not being met, the result of this was that priorities were constantly changing at the plant.

A changing schedule can help to explain why a plant suffers from poor delivery reliability. The continuous changing of schedules causes changing priorities on the shop floor, resulting in confusion and lurches in customer orders as some are moved ahead of others, the end result is that lead times begin to become extended for some orders (Plossl & Welch, 1979). The extension in manufacturing lead times means that some of the delivery due dates are missed , and so delivery reliability declines. Also, the continuous change in the schedule results in a loss of faith in the formal system, with the result that it is no longer believed in and used by the shopfloor, with its resultant implications for the future (Plossl & Welch, 1979).

To conclude, a number of differences are present, between the two groups, when it comes to production planning. All the plants in the high group developed the master production schedule on a monthly basis. Also, all the plants in the high group involved the Production Department in the approval of the MPS, thereby helping to ensure that is was realistic and achievable. However, in the low group, although the MPS was produced on a monthly basis, the Production Department was not involved in approving the master schedule at all the plants.

At all the plants in the high group, the detailed production schedule was approved by the Production department and experienced low variability. However, in the low group the detailed schedule was not always approved by the Production department. Also for a majority of the plants the schedule was not fixed and tended to vary. The continuous changing of schedules caused confusion on the shopfloor with customers' orders being moved around, the end result of which was that some delivery dates were missed.

7.7 FOCUS OF MANAGEMENT ON DELIVERY RELIABILITY

The degree of focus of the plant management on delivery reliability was drawn out from each of the case studies. It was possible to see the degree of focus on delivery reliability by examining the regular production related meetings that were held at each of the plants, the subjects discussed, and who attended the meetings. Table 7.10, shows the various production related meetings that took place across the various plants on a daily, weekly and monthly basis.

Overall, if we look at the 8 plants we find that all of them held regular monthly meeting, which all the key managers attended. An examination of the manufacturing meeting topics indicates that all the plants in the high group discussed delivery reliability at the monthly meetings, in fact it was one of the key topics discussed, and in the case of plant ELBHIGH it is the first subject of discussion

"Delivery is the first subject on the agenda, can we meet the customers requirements?" (Logistics Manager).

While at plant ELAHIGH the monthly meeting includes a review of performance that was very detailed going into delivery reliability performance customer by customer.

If we examine the low group, we can see that delivery reliability was not necessarily one of the key topics discussed at the monthly meetings for all the plants. For example, in the case of plant ENGBLOW the main focus of the discussion was profit and cash flow.

"The major topic of discussion at this meeting is profit and cash flow, that's what matter to head office and that's what matters to me" (General Manager).

Plant	Daily	Weekly	Monthly
ENG A HIGH	Production morning meeting chaired by general manager to review against the week's schedule. Production managers and materials manager attend. Each production manager has an end of shift meeting with supervisors to review progress against the schedule		Monthly managers meeting. All managers attend, the meeting reviews the performance in the previous month (including delivery reliability), quality, profit and sales revenue are discussed. Also the next month is discussed - forecasts, capacity requirements.
ENGB HIGH	Production meeting. Present: Operations Manager, Supervisors, and Production Controller subject: progress against schedule	Operations Manager and Commercial Manager meet to discuss the progress of production, fulfilment of customer orders.	Monthly managers meeting, all managers attend, subjects include production schedule, delivery reliability, profit and sales revenue Monthly forecasting meeting attended by General Manager, Commercial Manager, Operations Manager and Production Planning Manager. Meeting covers the forecast, forward planning, MPS and future capacity requirements.
ELA HIGH	Daily Production Meeting. Each Operations Manager holds such a meeting in their area. Planning Manger, Shift Manager and representatives from Engineering and Materials are present. Subject: progress against customer requirements, yesterdays performance, today's and to the end of the week.	Weekly Operations review. Chaired by the General Manager. Present: Operations Managers, Sales Manager, Account Managers, Finance Manager, Personnel Manager and Materials Manager. Subject: performance against customer delivery requirements, turnover, profit, quality, and customer complaints. These are reviewed by customer and in total.	Monthly Managers Meeting. Chaired by General Manager. Present: Operations Managers, Sales Manager, Account Managers, Finance Manager, Personnel Manager and Materials Manager. Subject: Progress for the month, delivery, sales, profit, overtime costs, quality, customer returns, forecasts and capacity issues. These are reviewed by customer and in total.
ELB HIGH	Twice per week there is a Production and Planning meeting. Chaired by Order Planning Manager Present: Materials Planners, Manufacturing Manager, and Order Planning Manager. Subject: Will all customer orders be shipped on-time. Will the plan for the month be achieved.	Weekly Planning meeting. Present: Order planners and Materials Planners. Subject: will the next weeks' orders be shipped on time, corrective action plans. Every two weeks there is a Forward planning meeting. Present: Materials planners, Production Manager, and Order Planning Manager. Subject: Forward plan and customer orders, will orders be shipped on time. Weekly Production Meeting. Chaired by the Manufacturing Manager. Present: manufacturing managers. Subject: weekly production, current plant loading and future loading.	Monthly Manager Meeting Chaired by Logistics Manager. Present: Manufacturing Manager, Order Planning Manager, Materials Planning Manager. Subject: Review of current plant performance starting with delivery reliability and then covering efficiency, inventory levels, quality and customer complaints.

ENG A LOW		Production, Planning and Customer Service meet to discuss the next week's schedule. Production, Planning and Customer Support also meet to discuss over-due orders and to agree plans to rectify the situation	Monthly managers meeting. All the key managers attend, the meeting covers the previous month's production, sales and profit, delivery reliability, and the likely situation for the next month.
ENGB LOW		General manager, Production Manager, Production Planning Manager, Quality Manager and Purchasing Manager meet weekly to discuss production and any problems. Production Manager meets with his team weekly to discuss production issues e.g. progress against schedule, supplier problems.	Monthly general management meeting. Attended by all the managers, the focus of the meeting is profit and cash flow.
ELA LOW	Daily Production Meeting. Chaired: Manufacturing Manager. Present: Section Managers. Subject: plants performance on the previous day, if any shortfalls occurred. Daily Planning Meeting. Chaired: Planning Manager. Present: Manufacturing Manager, section managers, Quality Assurance Manager. Subject: progress against the week's schedule, will today's schedule be completed, corrective actions to be taken, any changes to the schedule that need to be made.	Weekly staff meeting. Chaired: Plant Director. Present: Manufacturing Manager, Planning Manager, Finance Director and Personnel. Subject: progress against the schedule, priority orders, financial performance. Weekly small orders meeting. Chaired: Planning Manager. Present: Manufacturing Manager, Planning Manager and Marketing Manager. Subject: any small orders in arrears and action to be taken.	Monthly review meeting. Chaired: Plant Director. Present: Manufacturing Manager, Planning Manager, Finance Director and Personnel. Subject: progress made during the month, profit, sales, cash flow, labour variance, material variance, inventory levels, delivery reliability and factory yield rates.
ELB LOW	Daily Evening Meeting. Chaired by Plant Manager. Present: The two Production Managers. Subject: the day's production activities and the plans to be put into place to overcome any production problems and arrears.		Monthly Management meeting. Chaired by Plant Manager. Present: Production Managers, Planning Manager, Personnel Manager, and Finance Manager. Subject: performance for the month, profit, efficiency, quality, delivery reliability, customer complaints.

Table 7.10: Daily, weekly and monthly production related meetings.

However, overall the subjects discussed at the monthly meetings point to the fact that managers in both groups were, to varying degrees, discussing and examining delivery reliability even though for some it was not the major concern (i.e. plant ENGBLOW). The problem, of course, is that the by the time the monthly meeting is held it is too late to impact delivery reliability. A discussion of delivery reliability performance at a monthly meeting can only be a review about what has happened.

While all the plants held monthly meetings, the situation was different in the case of weekly and daily meetings. Taking weekly meetings first, in the high group all the plants except ENGAHIGH held weekly meetings, where the progress of the production plan was discussed and in particular whether customer orders would be shipped on-time. Plant ENGAHIGH, did not have any weekly meetings, because of the very short manufacturing lead times involved; daily meetings were considered to be more appropriate in their case.

The weekly meetings at the high group were concerned with the progress of production and in particular would next week's plan be met, and would customer orders be shipped on-time. At ENGBHIGH, the Operations Manager and the Commercial Manager met to discuss the progress of production and in particular meeting customer delivery dates:

"We review if we will hit customer dates ... if there are problems we try to come up with an action plan" (Commercial Manager).

The Operations Manager commented:

"The meeting covers will we ship customers' orders on time" (Operations Manager).

At ELAHIGH, there was a weekly operations review with the review being carried out customer by customer, one of the main concerns of the meeting was delivery reliability along side profit and quality:

"I expect every Operations Manager to ensure that we can ship everything as requested by the customer .. defect free and at a profit" (General Manager).

"We look backwards, how we did and forwards, will we be able to ship everything as requested" (Operations Manager).

In the case of ELBHIGH several meetings took place at the plant, all with the objective of ensuring that the customer orders are shipped on time. The meetings tended not just to look at the current situation, they also looked forward to ensure that future delivery dates were achieved:

"If one [an order] begins to slip we make sure it gets back on track" (Order Planning Manager).

"Early visibility of problems is important .... helps people develop action plans" (Materials Planning Manager).

Three of the plants in the low group also held weekly meetings; only plant ELBLOW did not hold weekly meetings. As in the high group, the meetings main discussion areas were the progress against the production plan, and also to determine if customers' order would be ready to be shipped by their delivery date. However, the difference that did exist between the two groups of plants was the fact that at two of the plants there was a meeting held specifically to discuss overdue orders, both plants ENGALOW and ELALOW held meetings to discuss overdue customer orders and when these would be completed and shipped to the customers concerned. The

management of plant ELALOW had to set up this meeting because in the past they had found that:

"small runs are likely to get lost" (Manufacturing Manager).

The problem was that the dates were often missed at ELALOW. As the Marketing Manager commented:

"The meeting was set up to keep an eye on those little orders for foreign countries where the orders are small [relative to the main customer], we need to have visibility of them ... If there was no meeting things could get missed" (Marketing Manager).

At plant ENGALOW a meeting (called the over-due orders meeting) was held on the Monday morning to discuss any over due orders from the previous weeks and any possible orders that may not be fulfilled in the current week:

"Monday we review the over-dues and plan to have them manufactured in the current week" (Production Controller).

The result of the meeting is a list of orders that need to be completed in the week, in addition to the orders in the current plan. The backlog that existed had to be added to the existing plan for the week with the result that the addition could result in the plant being overloaded, with the result that while the overdue were completed some of the other orders were not completed on time - valuable capacity was used instead to complete the overdue orders.

Plant ENGBLOW held meetings but it appeared that the managers accepted overdue orders as the norm, late delivery appeared not to be a pressing concern at the plant:

"We have some, it's normal, we had them at my last company" (Production Manager).

The use of over-due meetings at the two plants in the low group (and the fact that they were regular and formal events) was an indication that the degree of focus of management on delivery reliability was poor since customer orders had been allowed to miss their due dates and go into arrears. The managers were only dealing with the situation after the fact, rather than trying to stop it happening. It indicated that a lot of the managers were not focused on delivery reliability and ensuring customer orders were shipped on-time.

The situation with regard to daily meetings also points to a difference between the two groups of plants. Three plants in the high group (ENGAHIGH, ENGBHIGH and ELAHIGH) held daily meetings. Plant ELBHIGH did not have daily meetings but it had two meetings per week to review if customer orders would be shipped on-time.

In the case of the two plants (ENGAHIGH and ELAHIGH), with short manufacturing lead times, the daily meeting was crucial to ensure that orders were shipped on-time, to identify any possible problems and take the appropriate action. At ENGAHIGH a short Production meeting was held at the beginning of the day to review the previous day's production. The Managing Director at ENGAHIGH commented:

"Every morning I review if we met our customers' requirements ... if there were any problems yesterday which could impact our shipments today or tomorrow, they are discussed and corrective action is taken" (Managing Director).

As he also said:

"if a major disaster occurs we can do something about it, at 4.30 [p.m.] it is too late, it's history" (Managing Director).

Other managers confirmed the MD's continuous monitoring of performance:

"[MD] monitors the daily plan, so you need to ensure you hit it. The pressure is on you all the time" (Production Manager).

At ELAHIGH each Operations Manager would hold a daily production meeting (in the morning) for his area. The meeting covered the performance for the previous day, did they manufacture the quantity required by the customer and what the yield was (quality level). The meeting would also cover the day ahead;

"Do we have enough operators in today, what about tomorrow, are there any material issues we need to watch out for .. we often hold a conference call with the customer" (Operations Manager).

In the low group, only two of the plants held daily meetings. Both ELALOW and ELBLOW held daily meetings, and in both cases the meetings were used to decide the priorities for the following days, this situation was most evident at plant ELBLOW, where the next day's production priorities were actually decided resulting in the continuous change in the production schedule.

"At that meeting we decide which orders are urgent, which are overdue and must be despatched to the customer .... we decide which items get priority" (Production Manager)[3].

As the Plant Manager at ELBLOW commented about the meeting:

"The meeting is a review of the days production. At it we decide what orders should get priority tomorrow" (Plant Manager).

[3] The Production Manager also said that their contracts department would tell them if any important orders had missed their delivery date.

In the case of ELALOW, two daily meetings were held, the daily meetings discussed the previous day's production, if there were any shortfalls and what Production would manufacture in the next few days in order to make-up the arrears. The Production Manager would hold a Production meeting:

"Every morning at the Production Meeting we review what we did against the plan, then we sort out other issues and then prepare for the planning meeting at which we will plan out what we will do to recover" (Manufacturing Manager).

The Production meeting would then be followed by the Planning meeting where they would agree the action plans for the day and the rest of the week. At the Planning Meeting the Planning Manager would update the managers on what the previous day's output had been (they only got the output figure the following day). The Planning Manager commented that at the daily meeting they:

"we review what has been achieved against the plan for the week" (Planning Manager).

He backed up the comments made by the Manufacturing Manager that they used the meeting to set the targets for the future.

"This is what we did yesterday, we are down. You [Production] need to do this to recover" (Planning Manager).

However, ENGALOW and ENGBLOW did not hold any daily production related meetings. This deficiency in the case of ENGALOW, with its short lead times, meant that only at the weekly meeting was the situation with regard to customer orders discussed, by which time some of the orders would already be late. This fact goes some way to explain why ENGALOW had a weekly meeting to discuss overdue orders.

At ENGBLOW the overdues were discussed at the weekly meeting:

"Production Control will produce a list of items late and we will then discuss and set action plans" (Purchasing Manager).

However, as we have seen, the fact that the presence of a degree of overdue orders was considered acceptable meant that the management always discussed arrears at the weekly meeting.

In general, the managers in the plants in the high group were more focused on delivery reliability than the managers in the plants in the low group. In the high group the subject was discussed not just at their monthly meetings but also at weekly and daily meetings. The managers met and reviewed delivery reliability and ensured that actions were taken if a customer order looked in danger of being late. In the high group there was a process of continuously monitoring customer orders and every effort was made to ensure that orders were despatched on-time.

In the low group, although the subject of delivery reliability was discussed at the monthly meetings, the reality was that on a day-to-day basis the focus on delivery was weak, the only time delivery performance became an issue was when customer orders missed their delivery dates, it was at this point that the focus changed but of course by then it was too late.

Having examined the focus of the management lets now turn to the focus of the performance measurement system. The next section will examine this issue.

7.8 PERFORMANCE MEASUREMENT

Another area that was explored was the performance measures used in the plants. All the managers were asked which performance measures the plant should be good on, which measures they were monitored on, and also which key measures they monitored on a regular basis. Table 7.11, presents this information obtained about performance measures, it is important to note that the table is based on information provided by all the managers interviewed. If we compare the high and low group in terms of the extent to which delivery reliability was considered to be a key performance measure, we find that in the high group all the managers consider delivery to be important. However, in the low group we find that delivery was not considered to be a key measure; not all the managers in each plant considered delivery to be important. For example, in plant ENGBLOW, only two of the managers (Production Planning Manager and the Purchasing Manager) consider delivery reliability to be an important measure, the other managers did not mention delivery reliability; overall the most important measure at ENGBLOW was profit. Profit was not just a plant concern it was also a company wide concern, as the General Manager at ENGBLOW commented:

"All they [Head Office] are interested in is what's your profit" (General Manager)

The Production Manager backed up this view of the company:

"We are very finance driven" (Production Manager).

Plant	Extent to which delivery reliability is considered a key plant measure	Extent to which managers were monitored on the plants delivery reliability	Key measures managers monitor
ENGA HIGH	All managers consider delivery reliability to be important. Delivery reliability top of the General Manager's list.	Production manager and materials manager monitored on delivery reliability. Profit key for General Manager.	Most managers monitor delivery reliability - top of everybody list. Only Senior Buyer does not monitor delivery reliability.
ENGB HIGH	Most managers consider delivery reliability to be important. The General Manager has profitability top of his list.	Most managers (incl. General manager) monitored on delivery reliability - all except the purchasing manager. Profitability is key for the general manager	All managers monitor delivery reliability - although it is not necessarily the top measure for them.
ELA HIGH	All managers consider delivery reliability to be important. Delivery reliability is top of the list for General Managers and Planning Manager.	General manager, operations manager and planning manager monitored on delivery reliability. One of the main measures for Operations Manager.	All managers monitor delivery reliability, top of operations and Planning Managers list.
ELB HIGH	All managers consider delivery reliability to be important. It is top of every managers' list.	Logistics Manager, Materials Planning Manager and Order Planning Manager monitored on delivery reliability. One of the top measures for Logistics Manager	All managers monitor delivery reliability, it is top measure for all the managers.
ENGA LOW	All managers consider delivery reliability to be important. Production Director considers efficiency to be more important than delivery.	Nobody measured on delivery reliability. Production efficiency a key measure.	Nobody monitors delivery reliability. Production efficiency more important.
ENGB LOW	Few managers consider delivery reliability to be important only the Production Planning Manager and the Purchasing Manager. Profit is more important - it is top for all the managers.	Only Production Planning Manager monitored on delivery reliability. General Manager mainly monitored on profit and cash-flow.	All the managers monitor delivery reliability, but it tends to be a low priority on most managers' list. Profit is top for General Manager.
ELA LOW	Plant Director, Planning Manager and Marketing Manager consider delivery reliability to be important. Profit top of Plant Directors list.	Only Plant Director and Planning Manager monitored on delivery reliability. Profit is top of Plant Director's list.	Not all managers monitor delivery reliability - only Plant Director, Planning Manager and Marketing Manager. Delivery reliability is top of Planning Manager's list. Profit is the most important measure.
ELB LOW	Most of the managers considered delivery reliability to be important - but it is not top of everybody list. Plant manager considers efficiency to be more important.	Only Plant Manager and Materials Manager monitored on delivery reliability. But for both it is not the main measure. Plant output and labour efficiency more important for the Plant Manager.	Not all managers monitor delivery reliability - Plant Manager and Materials Manager monitors it. However delivery reliability is not top of their list.

Table 7.11: Plant performance measures.

If we turn our attention to the subject of which measure the managers were monitored on, we find that a large number of the managers in the high group were monitored against plant delivery reliability - the performance measurement system appeared to be focused on delivery reliability. It is also interesting to find that in three of the plants (except plant ELBHIGH) the Production Manager or Operations Manager was monitored on delivery reliability. At plant ENGBHIGH the Operations Manager and the Commercial Manager were monitored on delivery reliability, as the General Manager stated:

"on-time delivery has to be both their concerns, they both have a part to play" (General Manager).

Although the Production Manager at plant ELBHIGH was not monitored on delivery reliability, the overall importance that was attached to ensuring high levels of delivery reliability at the plant ensured that it was still a major concern for him.

In the low group, the number of managers monitored on delivery reliability was much smaller. At plant ENGBLOW, only the Production Planning Manager was monitored on delivery reliability. While at plants ENGALOW, none of the managers were monitored on delivery reliability - the performance measurement system lacked a focus on delivery reliability. Interestingly enough, at none of the four plants, in the low group, were any of the Production Managers monitored on delivery reliability.

The issue of which measures were monitored on a regular basis also brings out the differences between the two groups. In the high group most of the managers monitored delivery reliability; they were focused on a measure they considered to be important. At plant ENGAHIGH the General Manager, Production Manager and the Materials Manager all monitored delivery reliability, only the Senior Buyer did not monitor it. At plant ENGBHIGH all the managers (General Manager, Commercial Manager, Operations Manager, Production Controller and the Purchasing Manager)

monitored delivery reliability on a regular basis. At plant ELAHIGH all the managers (General Manager, Operations Manager, Planning Manager and the Purchasing Manager) monitored delivery reliability. While at plant ELBHIGH all the managers (Logistics Manager, Manufacturing Manager, Materials Planning Manager, Purchasing Manager and Order Planning Manager) also monitored delivery reliability.

However, in the low group, this clear focus on delivery reliability was missing, fewer managers monitored delivery reliability. At plant ENGALOW, we see the extreme example, there was an absence of focus on delivery reliability, nobody appears to monitor delivery reliability, in fact the managers were more concerned about arrears. At plant ENGBLOW although all the managers (General Manager, Production Manager, Production Planning Manager and Purchasing Manager) monitored delivery reliability, the measure was (except in the case of the Production Planning Manager) very low down their list of key measures monitored. At plant ELALOW only the Plant Director, Planning Manager and the Marketing Manager monitored delivery reliability but only in the case of the Planning Manager was it top of his list of key measures monitored. At plant ELBLOW only the Plant Manager and the Production Manager monitored delivery reliability, but in both cases it was not the most important measure on their list.

From Table 7.11, we can see that in the high group there was a high level of consistency between how important the managers said delivery performance was and what they actually monitored on a regular basis. In the high group the managers considered delivery reliability to be an important measure and they monitored it on a regular basis. There was a congruence between what was considered to be important and what the managers actually concentrated their attention on (Dixon et al, 1990). In the low group, we can see that there was a lack of congruence, plant ENGALOW is an extreme example of this, all the managers consider delivery reliability to be important, but in fact none of the managers mentioned they monitored delivery reliability on a regular basis. The reality was that other measures were more

important, in particular the efficiency measures - which were reported to Head Office. This lack of congruence was due to the influence of the performance measurement system, the system was encouraging the managers to concentrate on certain performance measures ahead, and in some cases, at the expense of others. Research carried out by Richardson and Gordon (1980), pointed to the fact that managers responded to those measures they felt their performance was being measured on. We can see this with all the plants in the two groups, for example at plant ELALOW, the Plant Director and the Planning Manager were monitored on delivery reliability and as we would expect they both monitored delivery reliability. The most extreme example is plant ENGALOW, where none of the managers interviewed were measured on delivery reliability and so consequently none of the managers monitored it on a regular basis.

If we compare the two groups we find that the focus of the performance measurement system in the high group was more towards delivery reliability. The situation was different in the low group - very few of the managers were monitored on delivery reliability and so the focus was not on this area. Now, it is a fact that some of the managers in the low group were monitored on delivery reliability in particular the Planning Managers at plants ENGBLOW and ELALOW and the Materials Manager at ELBLOW. However, this very functionally oriented approach will not produce the desired results unless there is a consistency of emphasis across the functional areas in the factory (Lockamy, 1994). To assume that because the Planning Manager is measured on delivery reliability then he will develop a plan that will ensure that the plant will meet all its delivery obligations, is to ignore the impact of all the other managers attempting to maximise their own performance, in particular the Production Manager. If the Production Manager is monitored on efficiency then, he will often produce jobs out of sequence, cherry picking those jobs that are easy to make, put similar jobs together to avoid set-ups, all with the result that while efficiency targets may be achieved some of the customers due dates will be missed (Fry & Cox, 1989). The production plan created to ensure high delivery reliability can very easily be

undermined by the Production Manager attempting to maximise his production efficiency performance. Lockamy (1994) points to the need for consistency in the measurement system focus, between organisational levels and across functions. We can see this consistency in the performance measurement system of the high group with a number of the managers in the different functions monitored on delivery reliability. However this consistency was missing in the low group with very few of the managers monitored on delivery reliability. At a number of the plants in the low group there was a lack of consistency in the performance measurement system. At plant ENGBLOW the Production Managers primary concern was production efficiency:

"The are targets set for efficiency for each production area, I make sure the team hits the targets" (Production Manager).

He had the added incentive to concentrate on this measure since as he stated:

" [General Manager] keeps a eye on this issue" (Production Manager).

This can be contrasted with the focus of the Production Planning Manager, that was delivery performance. With the overall company focus on financial performance, it is hardly surprising that delivery reliability took second place to financial performance.

At plant ELALOW a similar situation was present. The Plant Director stated that he had allocated specific responsibilities to the key managers:

"The Planning Manager looks after delivery, I have passed yield and labour efficiency to the Manufacturing Manager" (Plant Director).

The focus of the Manufacturing Manager was very much on labour efficiency:

"I keep a close eye on labour efficiency, if it falls I want to know why ... I use it to drive my team" (Manufacturing Manager).

The Planning Manager himself pointed to the focus of the plant when he stated:

"Labour efficiency is a key measure in the plant" (Production Planning Manager).

In the case of plant ELBLOW the Plant Managers main concern was the plant output:

"Every day I look at what the output has been for the previous day" (Plant Manager).

This concern about output had an impact on the evening meeting that was held, although the meetings covered plans to tackle important overdue orders it also covered the issue of whether the budget for the week would be achieved.

The lack of consistency in the performance measurement system, combined with the effect of each manager being driven by the performance measures he considers he is being measured on, led to sub-optimal result. With one group of managers focused on delivery reliability and another group focused on totally different measures, it is hardy surprising that the low groups delivery reliability suffered.

7.8.1 Delivery Reliability Targets

One piece of data that I was able to collect was the targets that were set for delivery reliability by the various plants. In the majority of cases the performance of the plant against the target was reported by the senior plant manager to his manager. Table 7.12 shows the targets the plants were set for delivery reliability.

Plant	Target	Reported to HO
ENGAHIGH	100%	No
ENGBHIGH	99%	Yes
ELAHIGH	100%	Yes
ELBHIGH	100%	Yes
ENGALOW	None	No
ENGBLOW	90%	No
ELALOW	95%	Yes
ELBLOW	90%	Yes

Table 7.12: Plant delivery reliability targets

The information presented in Table 7.12 indicates that the majority of the plants in the high group had targets for delivery reliability of 100% on-time delivery. While in the case of the low group the target levels varied from no target in the case of ENGALOW to 95% in the case of ELALOW. Taken as a whole the targets set for the plants in the low group did not appear to be very stretching when compared to the high group. This variation in the target levels is partly an indication of the level of delivery reliability that was considered to be acceptable in the low group.

If we refer back to the delivery reliability measurement system section we can see that in the case of ENGALOW, where nobody was measured on delivery reliability, the plant did not have a target for delivery reliability.

In the case of ENGBLOW the production planning manager told me that the target for delivery reliability was an internal one that was set for him to achieve because he was the only one monitored on delivery reliability.

In the case of ELALOW the plant director had stated that he was assessed against this target for the year. He informed me that in the previous year the plant had achieved

94% (against a target of 95%) and that his boss had been quite happy with the performance. However, the Plant Director also indicated that had he not achieved his profit target then his boss would not have been pleased. It would appear that achieving the plant delivery reliability target was in fact less important than achieving the target set for profitability.

If we examine the reporting of delivery reliability to head office we can see that there was no dramatic difference between the two groups; three of the plants in the high group reported their delivery reliability, while two of the plants in the low group reported their delivery reliability. The fact that the plants in the low group reported their delivery reliability to head office did not necessarily appear to drive them to achieve their targets.

7.9 FLEXIBILITY

Two areas of flexibility were investigated as part of the research, the two areas were:

Volume - the ability to change the level of the operations output

Mix - the ability to change the variety of products being made by the operations in a given time period.

In the case of volume flexibility, the research focused on how quickly the managers could increase output in the short term. While in the case of mix flexibility, the research examined how quickly the mix of products going through the plant could be changed in the short term. Table 7.13, shows the degree of flexibility that was reported by the managers for the 8 plants.

Plant	Volume flexibility	Mix flexibility
ENGAHIGH	High	High
ENGBHIGH	High	High
ELAHIGH	High	High
ELBHIGH	High	Low
ENGALOW	Low	Low in high vol. High in low vol.
ENGBLOW	Low	High
ELALOW	Low	High
ELBLOW	Low	Low

Table 7.13: Degree of flexibility for the eight plants.

Table 7.13 shows that the plants in the high performing group all had high levels of volume flexibility and the majority of the plants also had high levels of mix flexibility. If we compare the low group with the high group we can clearly see that the low group lacks volume flexibility. Plants that have high levels of volume flexibility have either spare capacity or possess the ability to very quickly increase capacity. If the plant does not have volume flexibility, when the level of demand increases it will experience increased load, increased congestion and the end result will be that some of the quoted delivery due dates will be missed. The plants in the low group who had low volume flexibility would find it very difficult to meet all their delivery promises should demand suddenly increase.

It is interesting that a number of plants in the low group did in fact claim to have high levels of mix flexibility. This property has allowed them to be able to change the mix of products on the shop floor, it allows them to react to the changing priorities on the shop floor. However, being able to switch quickly between products does not mean the plant can increase output, this ability only comes from having volume flexibility.

In conclusion, the main difference between the two groups of plants was that all the plants in the high group reported that they could increase output in the short term - they had volume flexibility. However all the plants in the low group reported that they could not increase output in the short term - they had low volume flexibility. Although most of the plants in the low group claimed to possess mix flexibility, this was no substitute for the lack of volume flexibility.

7.10 PROPOSITIONS

Having examined and compared the eight case studies, let us now review the four propositions and see if they are correct. Let us first deal with proposition 1:

> P1. In plants where the production planning department determines the delivery quotation, the level of delivery reliability will be high.

Figure 7.1 illustrates for the two groups whether, the Production Planning department or another department (such as Sales) was responsible for determining the delivery due date quotation. As we can see from Figure 7.1, there is a degree of distinction between the plants, all the plants with high delivery reliability had the Production Planning department determine the delivery date quotation. In the case of the plants with low delivery reliability, at two of the plants the Production Planning department produced the quotation, and at the other two, another department provided the quotation. In fact, in the case of one of the plants (ELALOW) where the Production Planning department was responsible for providing the delivery date quotation this did not necessarily happen all the time since there were occasions when the Marketing Department had provided the quotation without consulting the planning department. It would appear from the evidence that proposition 1 can be tentatively accepted.

	Production Planning (or similar department)	Another Department (i.e. Sales Department)
High delivery reliability	ENGAHIGH ENGBHIGH ELAHIGH ELBHIGH	
Low delivery reliability	ENGBLOW ELALOW	ENGALOW ELBLOW

Figure 7.1: The relationship between the level of delivery reliability and the department responsible for produced the delivery quotation.

As we saw in Section 7.3, the approach to quoting delivery dates also has a major impact. The evidence from the case study research points to the fact that where the plant based its quotation on load and capacity, rather than using standard lead times, it was likely to achieve high levels of delivery reliability. All the plants in the high group arrived at the delivery date quotation taking into account load and capacity. They did not base their quotations simply on standard lead times, thereby ignoring the current and future load being placed on the plant. Only one plant (ELALOW) in the low group took into account load and capacity when developing the delivery date quotation. However, the plant suffered from the problem that the Marketing department sometimes quoted delivery dates without consulting the plant management, and so was not always able to quote realistic delivery dates.

Let us now examine proposition 2, which is:

> P2. In plants where the customers have expectations of high levels of delivery reliability, the level of delivery reliability will be high

Figure 7.2 illustrates where the eight plants were positioned in terms of their delivery reliability against the extent to which they had demanding customers.

High delivery reliability	ENGAHIGH ENGBHIGH ELAHIGH ELBHIGH		
Low delivery reliability		ENGALOW ENGBLOW ELBLOW	ELALOW
	Demanding customers	Some demanding customers	No really demanding customers

Figure 7.2: Delivery reliability and demanding customers.

Figure 7.2 clearly shows the difference between the two groups of plants - all the plants in the high group had demanding customers, while those in the low group either had a few demanding customers or none at all. The case study evidence points to the fact that where the customers were demanding, the plants were forced to offer high levels of delivery reliability. Some of the plants in the low group had demanding customers, and were forced to provide them with high levels of delivery reliability. However, this high level of delivery reliability was not extended to those customers who were not demanding.

It would appear from the evidence that we can tentatively accept proposition 2. It would appear that plants who supply demanding customers will achieve high levels of delivery reliability. However, if only one or two customers are demanding, then, although these customers will receive high levels of on-time delivery, this

performance will not necessarily extend to the other customers who are less demanding.

In the case of proposition 3:

> P3. In plants where the plant's management team is predominantly focused on delivery reliability, the level of delivery reliability will be high.

Figure 7.3 shows the difference between the two groups of plants.

	Management team focused on delivery reliability	Lack of management team focus on delivery reliability
High delivery reliability	ENGAHIGH ENGBHIGH ELAHIGH ELBHIGH	
Low delivery reliability		ENGALOW ENGBLOW ELALOW ELBLOW

Figure 7.3: Delivery reliability and management team focus.

Overall, the focus of the managers in the high group was on delivery reliability, while in the low group this focus was weak: the attention of the plants in the low group tended to be mainly on the financial issues. Considering the case study evidence it would appear that we can tentatively accept proposition 3.

Finally, let us now examine proposition 4, which was as follows:

P4. In those plants where the performance measurement system has delivery reliability as a key area of focus, levels of delivery reliability will be high.

High delivery reliability	ENGAHIGH ENGBHIGH ELAHIGH ELBHIGH	
Low delivery reliability		ENGALOW ENGBLOW ELALOW ELBLOW
	Performance measurement system focused on delivery reliability	Performance measurement lacks focus on delivery reliability

Figure 7.4: Delivery reliability and performance measurement system focus.

In the case of proposition 4, there was a distinct difference in the focus of the performance measurement systems between the high and low groups - as we can see in Figure 7.4. The delivery reliability measurement system was focused on delivery in each of the plants with high levels of delivery reliability. In the low group, this clear focus on delivery reliability was missing, few of the managers were monitored on delivery reliability. The extreme example of the complete absence of a focus on delivery reliability was plant ENGALOW, at this plant, managers were not monitored on delivery reliability and consequently none of the managers monitored delivery reliability. The case study evidence indicates that proposition 4 can be tentatively accepted.

Plant	Quotation based on	Degree of demanding customers	Schedule Variability	Volume flexibility	Mix flexibility	Management focused on delivery ?	Performance measurement system focused on delivery ?
ENGAH IGH	Manufacturing lead times Load and capacity	Demanding customers - expect on-time delivery	None - fixed for A week. Small amount of variability for the month.	High	High	Yes	Yes
ENGB HIGH	Manufacturing lead times Load and capacity	Demanding customers - expect on-time delivery	None - fixed for month.	High	High	Yes	Yes
ELA HIGH	Manufacturing lead times Load and capacity	Demanding customers - one monitors plant on delivery reliability	None - fixed for the week.	High	High	Yes	Yes
ELB HIGH	Manufacturing lead times Load and capacity	Demanding customers - expect on-time delivery	None - firm for the month.	High	Low	Yes	Yes
ENGA LOW	Standard lead times	High volume customers demanding The other customer not particularly demanding	None - fixed for the week.	Low	Low in high vol. High in low vol.	No	No
ENGB LOW	Standard lead times For customer specials manufacturing lead times determined	Main customer demanding because of continuously changing requirements	High - changes over the month	Low	High	No	No
ELA LOW	Manufacturing lead times Load and capacity	Not particularly demanding, will accept late delivery	Some - changes over the month	Low	High	No	No
ELB LOW	Standard lead times	Major customer demanding, the rest are not as demanding	Some - changes over the month	Low	Low	No	No

Table 7.14: The key characteristics of the 8 case study plants.

7.11 CONCLUSION

Let us now examine the overall difference between the two groups of plants. Table 7.14 shows the characteristics of the 8 plants. The table indicates that the plants in the high delivery reliability group had the following characteristics:

- Developed their delivery date quotation by taking into account plant load and capacity.
- Supplied (mainly) very demanding customers, who expected high levels of delivery reliability
- Had a performance measurement system in place, that had delivery reliability as one of its main areas of focus.
- Had a management team that was focused (on a daily basis) on ensuring high levels of delivery reliability.

It would appear that from the case studies that there were a number of elements that contributed to the high group's good delivery reliability. They were able to quote realistic and achievable delivery dates because they quoted delivery dates taking into account load and capacity. Quoting a realistic delivery date is one element of enabling the plant to deliver on-time, the second is of course ensuring that the customers' order is completed by the quoted delivery date. The management of the plants in the high group were focused on delivery reliability and combined this focus was the influence of the performance measurement system which was also focused on delivery reliability. Alongside the management focus, was the external driver of customers demanding high levels of delivery reliability. These elements tended to maintain the concentration of the whole plant on the progress of customer orders and ensured that they achieve their quoted delivery date.

Table 7.14 also shows that the plants in the low delivery reliability group had the following characteristics:

- Developed their delivery date quotation based on standard lead times.
- Supplied a mix of demanding and undemanding customers.
- Had a performance measurement system that was not focused on delivery reliability - if anything the financial measures tended to exert a dominant influence.
- Had a management team that was not focused (on a daily basis) on ensuring high levels of delivery reliability.

Overall, the plants in the low group quoted delivery dates based on standard lead times, this approach committed them to dates that may not be achievable because this approach ignores the impact of future load and capacity. By taking this approach the management of the plants in the low group had set themselves a difficult task before they have even started to manufacture the product. The management lacked a focus on delivery reliability alongside which the performance measurement system was not focused on delivery reliability. Collectively, this meant that on a day to day basis the concern of the employees was on other areas, rather than ensuring that customer delivery dates were met.

The plants in the low group had a mix of demanding and undemanding customers that meant that they could trade off the different customer orders against each other. What the plants were forced to do was to manage customer order priorities, making sure that the important/urgent orders were shipped on-time, and those that were late were shipped as soon as possible. And because the plants supplied some undemanding customers they were able to manage this juggling of orders.

To conclude, the plants in the low group were likely to have over committed their capacity because at most of the plants a department other than the production planning department was responsible for determining the delivery date quotation. In addition, a majority of the plants were quoting delivery dates based on standard lead times. Alongside the fact that they had over-committed capacity, the plants also had

poor control of customer orders. This was caused by the lack of management focus on delivery reliability, and the negative impact of the performance measurement system that was more financially orientated. The other factor that contributed to poor delivery reliability was the lack of volume flexibility. Had the plants in the low group supplied only demanding customers they would have been driven not to over commit capacity and so they would have been in a better position to meet delivery promises.

CHAPTER EIGHT

COMBINED RESEARCH RESULTS

8.0 INTRODUCTION

In Chapter Six the results of the survey analysis were presented. The relationships between a number of variables and delivery reliability were examined. The variables discussed included complexity, customisation, supplier delivery reliability and demand variability. Chapter Seven covered the results of the case study stage of the research, and the relationships between a number of other variables and delivery reliability. These included, the quotation process, the focus of the management, and the focus of the performance measurement system. The current chapter uses the results from the previous two chapters to extend the understanding of the factors that influence delivery reliability. We start by re-introducing the conceptual model of delivery reliability. Then taking each key variable shown in the model, the chapter re-examines the nature of the relationship of each variable with delivery reliability.

8.1 THE CONCEPTUAL MODEL

In Chapter Four a conceptual model of the major factors that influence plant delivery reliability was derived, based on the literature review. Figure 8.1 shows the model, indicating the factors, both internal and external to the plant, that impact plant delivery reliability.

The survey and the case study stages of the research investigated various elements of the model. The survey was used to examine the following elements

- Customisation
- Part complexity

- Supplier delivery reliability
- Demand uncertainty

The case study stage of the research was primarily used to examine the following elements:

- Quotation
- Management focus on delivery reliability
- Focus of the performance measurement system on delivery reliability
- Demanding customers

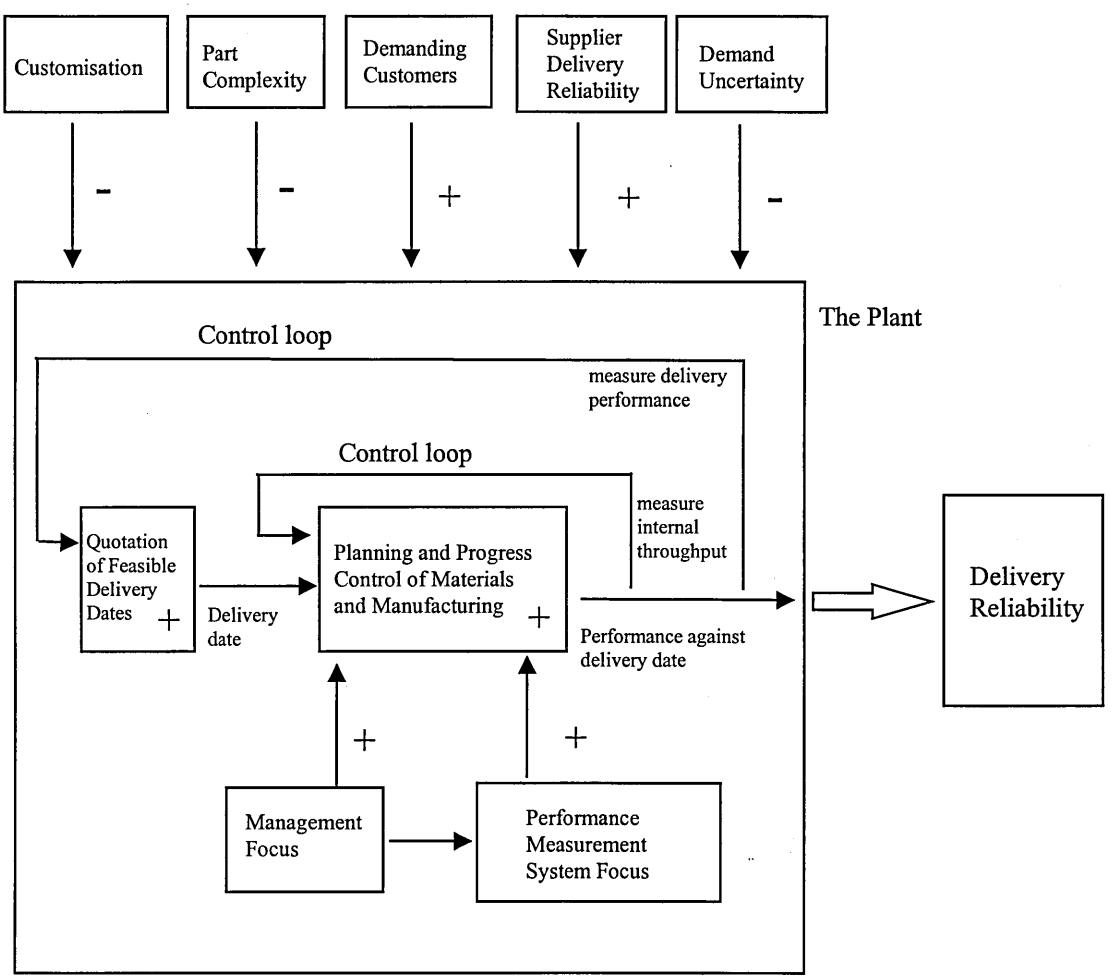

Figure 8.1: Conceptual model of delivery reliability.

Taking the results from the two stages of the research together, it is possible to explore the nature of the relationships between the various elements of the model and plant delivery reliability. Let us start by examining the external elements (external to the plant), these are covered in Section 8.2. The internal elements will be then discussed in Section 8.3 and finally, Section 8.4 covers the overall findings of the research.

8.2 EXTERNAL COMPONENTS

The model shows the five external factors that impact delivery reliability. This section looks at the relationship between each of the five factors and plant delivery reliability. The section starts by looking at customisation and its relationship with delivery reliability. The next area examined is that of part complexity, it is followed by demanding customers. The relationship between supplier delivery reliability and delivery reliability is covered in the next section (Section 8.2.4). The final area that is discussed is that of demand uncertainty.

8.2.1 Customisation

The survey stage of the research (as covered in Chapter Six) examined the relationship between customisation and plant delivery reliability. The results of the regression analysis indicated that there was a negative relationship between the proportion of customised products and plant delivery reliability. Consequently, at those plants where customised products took up a large proportion of output, delivery reliability was low. While, at those plants where customised products took up a smaller proportion of output, delivery reliability was high. The results appeared to support the (negative) relationship between the proportion of customised products and plant delivery reliability presented in the conceptual model (Figure 8.1).

The case study stage of the research also help us to examine the impact of customised products. The case study plants had been originally selected and paired so that differences in the level of customisation were controlled for[1]. However, some of the plants selected manufactured a proportion of their output as customised products and so it was possible to examine the difficulties they faced in dealing with such products. Table 8.1 shows the proportion of output devoted to customised products for the eight case study plants. The table indicates that each group (low and high delivery reliability) contained some plants that manufactured customised products, although none of the plants devoted more than 25% of its output to such products. It also illustrates the fact that the plants in the high group manufactured customised products and yet still achieved high levels of delivery reliability.

Plant	Proportion of output devoted to customised products
ENGAHIGH	0%
ENGBHIGH	10%
ELAHIGH	5%
ELBHIGH	10%
ENGALOW	10%
ENGBLOW	25%
ELALOW	0%
ELBLOW	5%

Table 8.1: Proportion of output manufactured as customised products.

Reviewing the case study data indicated that there was a difference in the approach adopted by the two groups of plants in arriving at the delivery date quotation. Table

[1] An attempt was made to try to ensure that the level of customisation did not vary dramatically between the two plants (in a pair).

8.2 presents[2] the approach adopted by those plants that manufactured customised products.

Plant	Quotation for customised products based on
ENGBHIGH	Manufacturing lead times, load & capacity
ELAHIGH	Manufacturing lead times, load & capacity
ELBHIGH	Manufacturing lead times, load & capacity
ENGALOW	Standard lead times
ENGBLOW	Manufacturing lead times
ELBLOW	Manufacturing lead times

Table 8.2: The methods used to arrive at delivery quotation for customised products.

From Table 8.2 we can see that all the plants in the high group (which manufactured customised products) developed their quotation for customised products taking into account load and the capacity of the plant.

However, in the low group of plants the situation was different. ENGALOW based its quotation on standard lead times, although these were much longer than for their normal products. While ENGBLOW and ELBLOW determined the delivery date based on the manufacturing lead times for the customised product. The Production Planning Manager at plant ENGBLOW admitted that they sometimes had problems in quoting feasible delivery dates, because they had difficulty accurately estimating how long it took to manufacture a customised product. Using just manufacturing lead times does not allow for the determination of a realistic delivery date because such an approach ignores the impact that the other orders in the factory will have on the actual lead time (of the order). The estimation of a realistic delivery date requires knowledge of the load placed on the plant, the capacity available and any other outstanding

[2] The table only shows the method used for those plants that actually made any customised products.

commitments. Therefore, the approach adopted by plants in the low group would not result in the quotation of feasible delivery dates.

Once the order has been accepted for a customised product, problems may still be experienced. For example, stoppages in the manufacture of an order due to quality problems may be more common. This is because some of the products may not have been manufactured before so the likelihood of mistakes is much higher. The delays in production may increase the manufacturing lead time and result in delivery dates being missed. Evidence from the case study research indicates that for some of the plants in the low group, quality problems were more pronounced with customised products. The Production Manager at ENGBLOW made the observation that customised products were sometimes delayed due to parts being scrapped because of quality problems or because employees had mis-read the drawings.

While the Production Manager at plant ELBLOW made the following comment:

"Customer specials can suffer from quality problems such as missing components, people have less experience making them so don't spot anything until it's picked up at test and of course by then you've made a couple of hours' worth" (Production Manager).

An important activity to ensure that delays do not result in failure to deliver on-time is progress control. The evidence from the case studies suggests that in the high group of plants the progress of orders was monitored on a regular basis and if an order looked as it was not going to meet its delivery date, corrective action would be taken. This focus on ensuring that orders met their delivery dates applied to both standard and customised products.

However, in the low group of plants there was less monitoring of customer orders when compared to the high group. The general approach tended to be reactive, rather

than proactive. There was little monitoring of customised orders, the end result of this was that some did not achieve their delivery date.

In summary, the research results relating to customisation suggest a number of points:

- There was a negative relationship between the proportion of customised products manufactured and plant delivery reliability.
- Plants that achieved high levels of delivery reliability adopted an approach that ensures that feasible delivery dates were quoted for customised products
- Plants with high levels of delivery reliability monitored the progress of orders (for customised products) on a regular basis

8.2.2 Part Complexity

The survey data was analysed to determine if a relationship existed between part complexity and plant delivery reliability. The results of the regression analysis indicated that the hypothesis H2 could not be accepted and so the null hypothesis was accepted. The regression analysis did not find any relationship between the two variables. So, for example, plants with very complex products enjoyed the same level of delivery reliability as plants making very simple products.

The case study plants had been selected to ensure that the level of part complexity did not vary between the two plants that made up a pair. However, there was a difference between pairs. For the engineering group ENGBHIGH and ENGBLOW made more complex products than ENGAHIGH and ENGALOW. While in the electronics group ELBHIGH and ELBLOW made a more complex product than ELAHIGH and ELALOW. The case study results indicate that it is possible to make a complex product and still achieve high levels of delivery reliability, but it is equally possible to make a complex product and have poor delivery reliability.

The plants that manufactured complex products and achieved high levels of delivery reliability were undertaking a number of activities that were helping to ensure high levels of delivery reliability. These plants quoted feasible delivery dates, they monitored the progress of orders and were proactive in taking actions to ensure that delivery dates were met.

The plants in the low group that manufactured complex products did not undertake the same actions as the plants in the high group. Their actions could have contributed to their poor delivery reliability

In summary the research results relating to customisation suggest that:

- There is no relationship between part complexity and plant delivery reliability.

8.2.3 Demanding Customers

In Chapter Six, the survey results indicated that there was a significant positive relationship between the extent to which the customer determined the delivery date at the quotation stage and the level of plant delivery reliability. The results suggested that where the customer had the major say about the quoted delivery date, the plant would have high levels of delivery reliability. However, when the customer had little influence regarding the quoted delivery date then the plant's delivery reliability would be low. The survey results suggest that those customers who had a major influence on the delivery date quotation were likely to be very demanding and would therefore demand that the quoted delivery dates were honoured. However, the survey only examined the influence of the customer on setting the delivery date; the survey did not specifically examine the impact of demanding customers on the achievement of those quoted delivery dates.

However, the case study stage of the research helped to give a better understanding of the impact of demanding customers. The analysis of the case studies found that the

four plants with high levels of delivery reliability all had demanding customers - they all demanded very high levels of delivery reliability. For example, one of the plants (ENGAHIGH) supplied a car assembly plant, any late delivery to this factory could result in car production stopping. If the supplier caused the car assembly plant to stop production due to poor delivery this would result in a large fine and the loss of future business.

In the case of the four plants with low delivery reliability the position was different. Three of the four plants (ENGALOW, ENGBLOW and ELBLOW) in the low group supplied a few demanding customers. The remaining customers were not so demanding and so were prepared to accept late delivery. The demanding customers' orders received priority ahead of the other orders. The result of this was that the demanding customers enjoyed high levels of delivery reliability while the less demanding customers received some of their orders late.

To be able to meet the demands of the demanding customers for high levels of delivery reliability the plants in the high group appeared to possess a number of characteristics. At the quotation stage the plants had to quote feasible delivery dates. The Commercial Manager at ENGBHIGH had stated that they, as a plant, had spent a lot of time explaining the importance of offering an accurate delivery date (to be able to achieve on-time delivery). All plants with high levels of delivery reliability used an approach to quoting delivery dates that would result in a feasible delivery date being quoted.

To ensure that the orders achieved their delivery dates meant that the management also had to be focused on delivery reliability. The management at the high group of plants were all focused on delivery reliability. They understood the importance to the customer and to their own plant of achieving high levels of delivery reliability. The focus of the management meant that the progress control of orders was carried out continuously to ensure that orders achieved their delivery dates.

However, at the plants with low levels of delivery reliability the situation was different. Since they did not use an approach that ensured they quoted feasible delivery dates they were forced to take action at a later stage (when the product was being manufactured) to ensure that their demanding customers' orders achieved their delivery dates. The plants had to change priorities in the factory to ensure that the demanding customers they supplied received high levels of delivery reliability. At plant ELBLOW one of the factors that caused them to change priorities at the "evening meeting" was the need to meet delivery dates for the major customer (a demanding customer). The result was that the demanding customers received their orders on-time, but at the expense of the less demanding ones, who received some of their orders late.

In summary the key points that emerge from the overall research results relating to demanding customers are as follows:

- There was a positive relationship between demanding customers and plant delivery reliability.
- Plants supplying mainly demanding customers achieved high levels of delivery reliability. While plants supplying a few demanding customers provided them with high levels of delivery reliability at the expense of the remaining customers. So overall these plants delivery reliability was low.
- Plants supplying mainly demanding customers used an approach that ensured they quoted feasible delivery dates.
- Plants that supplied mainly demanding customers had a management team focused on delivery reliability.

8.2.4 Supplier Delivery Reliability

The survey stage of the research examined the relationship between supplier delivery reliability and plant delivery reliability. The survey analysis found that there was a

strong positive relationship between supplier delivery reliability and plant delivery reliability. This suggests that plants that enjoyed high levels of supplier delivery reliability also had high levels of delivery reliability. In contrast those plants with poor supplier delivery reliability also had low levels of delivery reliability. The results of the survey analysis confirmed the relationship postulated in the model.

The case study stage of the research also indicates the impact of supplier delivery reliability. A number of the plants (in both the high and low groups) commented that poor supplier delivery reliability could result in them missing delivery dates. For example:

"If we are going to deliver on-time, we need our suppliers to deliver on-time" (Purchasing Manager ELAHIGH).

All the plants (in the high and low groups) measured their suppliers delivery reliability performance, Table 8.3 presents the data about each plants level of supplier performance and shows that the plants with high levels of supplier delivery reliability also achieved high levels of plant delivery reliability. These results appear to be in

Plant	Supplier Delivery Reliability
ENGAHIGH	96%
ENGBHIGH	95%
ELAHIGH	95%
ELBHIGH	96%
ENGALOW	65%
ENGBLOW	90%
ELALOW	82%
ELBLOW	85%

Table 8.3: Supplier delivery reliability for each of the 8 case study plants.

line with the survey results reported earlier. Table 8.3 indicates that both groups of plants measured their supplier delivery reliability. However, the plants in the high group were able to get much better levels of performance out of their suppliers than the plants in the low group.

The case study research indicates that there was a difference between the two groups of plants. The managers in the high group of plants were focused on delivery reliability and this had an influence on their approach to progress control. As part of this activity attention was paid to supplier performance, their performance was regularly monitored and problems were discussed and corrective actions agreed. The plants in the high group paid close attention to their suppliers performance to ensure that shortages of components and raw materials did not occur. For example, the Operations Manager at ELAHIGH said:

"The Materials Manager is in regular contact with our parts suppliers keeping them up to date with our position, making sure they keep us supplied."

At ELBHIGH the Material Planning Manager made the following comment:

"We keep a eye on our key components, what's the stock level, when are deliveries due"

The situation at the low group of plants was different. The management was not focused on delivery reliability and they tended to have a reactive approach to progress control. In the low group of plants the day-to-day focus on delivery reliability was weak. There was a lack of continuous monitoring of customer orders. This meant that the plants tended to react to the problems caused by poor supplier delivery reliability. For example, the Manufacturing Manager at ELALOW commented:

"We have had problems with late delivery of plastics [plastic components] this has meant we have had to change the schedule"

However, the problem of poor supplier delivery performance may have actually been caused by the actions of the customer, for example, asking for delivery earlier than agreed. Certainly in the case of plant ENGBLOW, the Planning Manager stated that sometimes they forced their suppliers to delivery earlier than agreed. The result of this was that sometimes the suppliers' shipments were late or the plants received only part-shipment.

To sum up, the plants in the low group were forced to try to manage their way out of the problems caused by poor suppliers delivery reliability. While the plants in the high group tried to ensure that they did not suffer from poor supplier performance in the first place.

In summary the key points that emerged from the overall research results relating to supplier delivery reliability are as follows:

- There was a positive relationship between supplier delivery reliability and plant delivery reliability.
- Plants (with high levels of delivery reliability) that monitored supplier delivery reliability as part of progress control also enjoyed high levels of supplier delivery reliability.

8.2.5 Demand Uncertainty

The survey data was analysed to examine the relationship between demand uncertainty and plant delivery reliability. The survey analysis uncovered that there was a negative relationship between demand uncertainty and delivery reliability. The results of the analysis indicated that plants that experienced high levels of unpredictable customer demand had low levels of delivery reliability. While, plants

that enjoyed low levels of unpredictable customer demand, had high levels of delivery reliability. The results of the summary analysis appear to support the postulated relationship outlined in the model.

The case study stage of the research helped to examine the issue of demand uncertainty; Table 8.4 shows the levels of demand uncertainty faced by the eight plants (i.e. 1 is highly predictable, while 5 is highly unpredictable).

Plant	**Demand Uncertainty**
ENGAHIGH	2
ENGBHIGH	3
ELAHIGH	3
ELBHIGH	3
ENGALOW	3
ENGBLOW	5
ELALOW	4
ELBLOW	3

Table 8.4: Demand uncertainty levels for each of the 8 case study plants.

Three of the plants in the high group stated they experienced medium levels of uncertainty, while the remaining plant experienced a slightly lower level. Two of the plants in the low group higher levels of demand uncertainty. The Production Planning Manager at plant ENGBLOW stated that they faced a high level of uncertainty because their customers final demand was so difficult to predict.

"You might hear on the grapevine about a new contract, but otherwise you're in the dark" (Production Planning Manager).

Overall, it was the plants in the low delivery reliability group of plants that experienced the higher levels of demand uncertainty.

One way to deal with demand uncertainty is to have spare capacity and/or to change the quoted lead times and quote longer lead times to take account of the increased load. The problem for the low group was that they did not have the ability to increase their output because they did not have a lot of spare capacity and so they could not cope with a sudden increase in demand (both ENGBLOW and ELALOW would have experienced the greatest uncertainty). Their ability to deal with demand fluctuations, would not have been so severely handicapped had they been able to vary their quoted delivery lead times. However, a number of them (ENGALOW, ENGBLOW and ELBLOW) quoted standard lead times and so they had little room for manoeuvre. The result of this lack of ability to cope with the demand fluctuation forced them to manage their order priorities. This particular course of action meant that they had to decide which orders had the highest priority (and so met their delivery dates). However, some of the orders would have a low priority and so would not meet their delivery date, the end result was that the plant overall delivery reliability would suffer.

In summary the key points that emerge from the overall research results relating to demand uncertainty are as follows:

- There was a negative relationship between demand uncertainty and plant delivery reliability.
- The plants with poor delivery reliability were unable to deal with the impact of demand uncertainty because they lacked spare capacity.

8.3 INTERNAL COMPONENTS

This section will examine the components that reside within the plant (as shown in Figure 8.1). The section starts by looking at the relationship between the focus of management and delivery reliability (Section 8.3.1). The next area examined is that of

the focus of the performance measurement system. The section then goes on to cover the quotation of feasible delivery dates and it finishes with planning and progress control.

8.3.1. Management Focus

During the case study stage of the research the issue of management focus and its relationship with delivery reliability was examined. The results of the analysis identified that at all the plants with high levels of delivery reliability the management teams were focused on delivery reliability. In the high group of plants, the subject of delivery reliability was an important subject at all the management meetings. All the plants in the high group held monthly meetings where one of the key topics was delivery reliability. Three out of the four plants (ENGBHIGH, ELAHIGH and ELBHIGH) held weekly meetings where again the issue of delivery reliability was discussed, in particular, would the customer orders be shipped on-time? In the case of daily meetings three out of the four plants (ENGAHIGH, ENGBHIGH and ELAHIGH) held daily meetings where, again one of the major subjects was delivery reliability, especially would the customers orders be shipped on-time. The emphasis on delivery reliability was consistent at all the plants, it was a major topic of concern at all the meetings. The managers all monitored delivery reliability (see Section 7.8). They also discussed delivery reliability on a regular basis, and ensured that actions were taken if a customer order was in danger of being late. In the high group of plants the management team were continuously focused on delivery reliability.

In the low group of plants the situation was different. All the plants in the low group held monthly meetings at which, in the majority of cases, delivery reliability was discussed. Three of the plants (ENGALOW, ENGBLOW and ELALOW) in the low group held weekly meetings. At these weekly meetings the issue of delivery reliability was discussed. However, at two of these plants (ENGALOW and ELALOW) a weekly meeting was held specifically to discuss orders that were late, and when they

would actually be shipped to customers. These meetings were regular and formal. Only two of the plants (ELALOW and ELBLOW) in the low group held a daily meeting. In both cases, the meeting was used to discuss the production priorities for the next few days. At both these plants the meeting tended to be reactive in nature, they discussed those orders that had missed their delivery dates. In the low group of plants, although delivery reliability was discussed at the monthly management meetings, the reality was that on a day-to-day basis the focus on delivery was weak. Interviews with the managers uncovered that very few of them monitored delivery reliability on a regular basis. The only time delivery reliability became an issue was when a customer order missed its delivery date, it was at this point that the focus changed towards delivery reliability.

The finding from the case study stage of the research supports the relationship presented in the conceptual model. The model proposes that there was a positive relationship between management focus and delivery reliability, this appears to be confirmed by the research. The plants where the management team was focused on delivery reliability also achieved high levels of delivery reliability.

The focus of the management has implications for the quotation and the planning and progress control activities. If the management is focused on delivery reliability it is likely to take steps to ensure that feasible delivery dates are quoted. If we examine the plants in the high group we can see that they all use an approach (taking into account load and capacity) that allowed them to quote feasible delivery dates. Certainly, in the case of ENGBHIGH management effort was put into ensuring that accurate delivery dates were quoted to customers. The Commercial Manager pointed out during the course of the interview that they had spent a lot of time explaining to all the relevant staff the importance of offering accurate delivery dates.

The focus of the management on delivery reliability was poor at the plants with low levels of delivery reliability. The majority of the plants used an approach to

developing the delivery date quotation that would not necessarily result in the quotation of a feasible delivery date. If the management had been focused on delivery reliability it is probable that they would have ensured that only feasible delivery dates were quoted.

The case study evidence suggests that the nature of progress control activity was related to the focus of the management team. In the high group of plants the managers monitored delivery reliability, they also monitored customer orders and they took action when necessary to ensure that customer orders met their delivery dates. The flow of orders was actively managed to ensure they achieved their delivery dates.

In the low group of plants the progress control was poor. It was reactive in nature with actions being taken to deal with orders that had missed their delivery dates. Corrective action was agreed so that the orders were shipped as soon as possible.

In summary, the overall research results relating to management focus are as follows:

- There was a positive relationship between management focus on delivery and plant delivery reliability. The plants where the management was focused on delivery reliability would also achieve high levels of delivery reliability.
- Where the management was focused on delivery reliability procedures were followed that provided for a feasible delivery date to be quoted.
- Where the management was focused on delivery reliability then the progress control of orders would be proactive in ensuring that orders achieved their delivery dates.

8.3.2 Performance Measurement System

During the case study stage of the research, the issue of performance measurement system focus and its relationship with delivery reliability was examined. In the high group of plants the focus of the performance measurement system was on delivery

performance. A large proportion of the managers were monitored on their plants delivery reliability performance, and in turn, most of the managers monitored their plants performance.

In the case of the low group of plants very few of the managers were monitored on delivery reliability - there was a lack of focus of the performance measurement system on delivery reliability. At one plant (ENGALOW), none of the managers were monitored on delivery reliability. While at another plant (ENGBLOW), only the Production Planning manager was monitored on delivery reliability. Along side the lack of focus of the performance measurement system on delivery reliability, was the fact that few of the managers monitored delivery reliability on a regular basis.

The conceptual model proposed that there was a positive relationship between performance measurement system focus on delivery reliability and plant delivery reliability. The findings from the case study stage of the research confirmed the relationship presented in the conceptual model.

In summary, the research results relating to the performance measurement system focus are as follows:

- There was a positive relationship between the focus of the performance measurement system on delivery reliability and plant delivery reliability.
- The performance measures a manager was monitored on influenced the performance measures he/she monitored.

8.3.3 Quotation of Feasible Delivery Dates

The case study stage of the research examined the process of delivery date quotation. The two key elements of this process that were examined were: which function was responsible for developing the delivery date quotation; and what was the approach used to determine the delivery date.

The case study stage of the research indicated that at the plants with high levels of delivery reliability the production planning department was responsible for the delivery date quotation. However, at plants with low delivery reliability this was not the situation, there was a tendency for other departments to be responsible for the delivery date quotation. The case study research points to the fact that where the production planning department is not involved in developing the quotation then it is likely that the plant delivery reliability will be poor.

However, while ensuring the appropriate department is responsible for determining the delivery date quotation is important, it is only one of the elements of ensuring high levels of delivery reliability. Another element that is important is the method used to arrive at the delivery date quotation. As part of the case study research the approach used to determine the delivery date was investigated. All the plants with high levels of delivery reliability developed their delivery quotation taking into account the load and capacity of the plant. While the majority of the plants with low levels of delivery reliability based their delivery date quotation on standard manufacturing lead times.

The use of standard manufacturing lead times, in the quotation process, does not provide the correct delivery date because it ignores the impact of the other orders in the factory or its capacity. Quoting delivery dates based on standard manufacturing lead times will result in the plant not being able to meet all its delivery promises, if the plant becomes overloaded and capacity cannot be expanded.

In summary, the research results relating to the quotation of feasible delivery dates are as follows:

- There was a positive relationship between the quotation of feasible delivery dates and plant delivery reliability. Plants with high levels of delivery reliability plants adopted an approach for developing the delivery date quotation which ensured that feasible delivery dates were quoted.

- To arrive at feasible delivery dates the plants adopted an approach for developing the delivery date quotation took into account the load and capacity of the plant.
- Also, the plants with high levels of delivery reliability had the production planning department responsible for the quotation.

8.3.4 Planning and Progress Control

Being able to quote feasible delivery dates is not sufficient to ensure that high levels of delivery reliability are achieved. The orders must still be monitored and progress control carried out, to ensure that the customers' orders proceed through the factory and achieve their delivery date. The plants in the high group, not only did they adopt practices that ensured they quoted feasible delivery dates they also proactively made sure that the orders achieved their delivery dates. Both elements were present in the plants with high levels of delivery reliability.

At the plants with high levels of delivery reliability the managers were focused on delivery reliability. They monitored delivery reliability, they all knew it was important to achieve high levels of delivery reliability and they made sure that actions were taken to ensure that it was achieved. The approach to progress control at the plants with high levels of delivery reliability was proactive in approach. Regular meetings were held, where the progress of orders was reviewed. If orders were in danger of missing their delivery dates corrective action was agreed

Overall in the low group of plants there was much less monitoring of customer orders taking place when compared to the high group. The general approach to progress control in the low group of plants was reactive, rather than proactive. Action tended to be taken when an order had missed its delivery date. This was partly influenced by the lack of management focus on delivery reliability. Very few of the managers were focused on delivery reliability and so consequently the approach to the progress of orders was reactive in nature.

In summary, the overall research results relating to the planning and progress control area are as follows:

- There was a positive relationship between the planning and progress control and delivery reliability
- Plants with high levels of delivery reliability monitored the progress of orders through the factory on a regular basis
- Plants with high levels of delivery reliability had a proactive approach to planning and progress control.

8.4 REVISED MODEL

This chapter has covered the findings from the case study and survey stages of the research. Taken together the research results suggest that a number of variables impact plant delivery reliability. The conceptual model of delivery reliability was revised as a result of the research findings. Figure 8.2 shows the revised conceptual model.

The revised model indicates that several factors are related to delivery reliability. The external factors are: customisation, demanding customers, supplier delivery reliability and demand uncertainty. While the internal factors are: the quotation of feasible delivery dates, planning and progress control of materials & manufacturing, management focused on delivery reliability, and performance measurement system focused on delivery reliability.

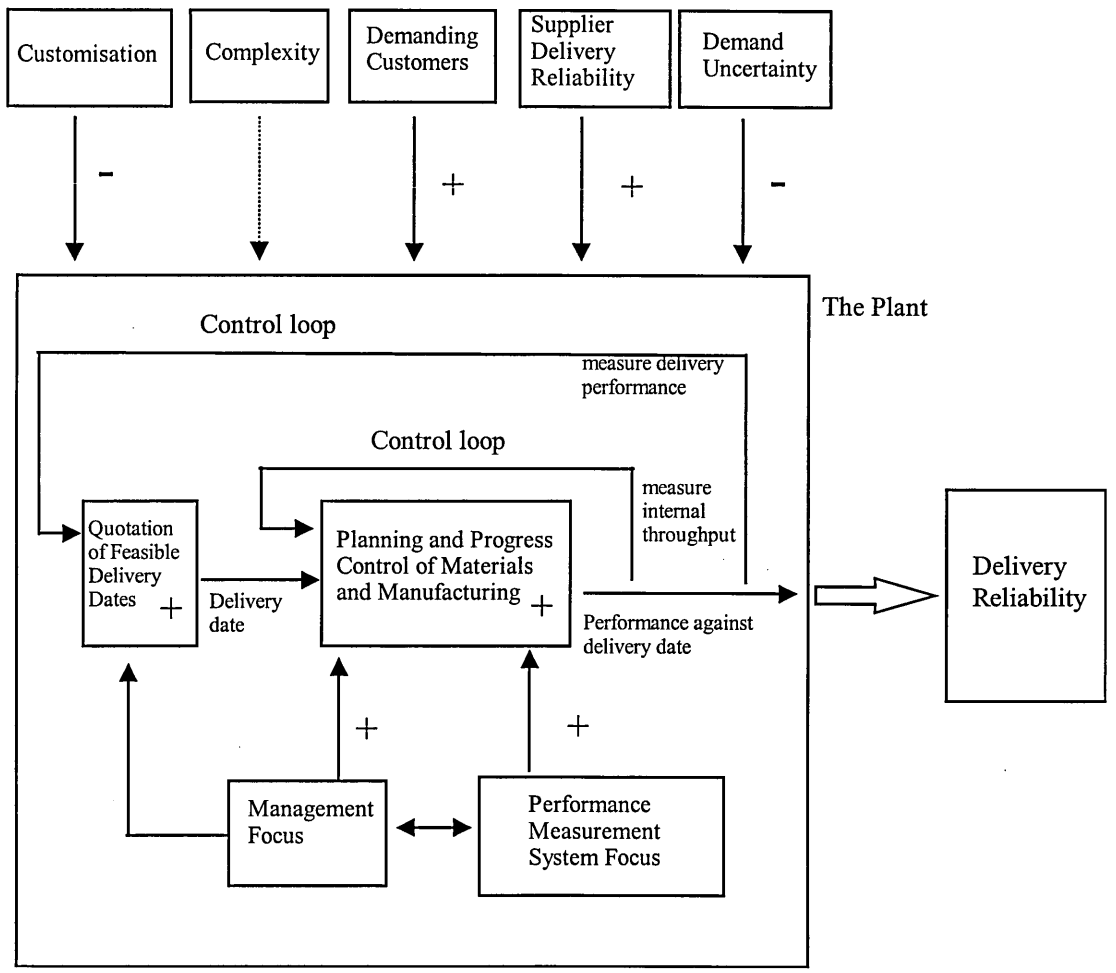

Figure 8.2: Revised conceptual model of delivery reliability.

Overall, the research indicates that the plants with high levels of delivery reliability had different characteristics compared to the plants with low levels of delivery reliability. Table 8.5 shows the characteristics of the plants with high and low levels of delivery reliability.

Factor	High Levels of Delivery Reliability	Low Levels of Delivery Reliability	Comments
Customisation	Manufacture a low proportion of customised products	Manufacture a high proportion of customised products	Impact can be reduced by quoting feasible delivery dates, focusing on delivery
Demanding customers	Supply mainly demanding customers	Supply few or no demanding customers	This factor can also impact management focus, quotation of delivery dates, and planning and progress control
Supplier delivery reliability	Enjoy high levels of supplier delivery reliability	Experience poor supplier delivery performance	Impact can be reduced by active monitoring and corrective action
Demand uncertainty	Have low demand uncertainty	Have high demand uncertainty	Impact can be reduced by being able to increase output and change delivery dates at the quotation stage
Management focus	Management focused on delivery reliability	Management not focused on delivery	Performance measurement system focused on delivery also needs to be present
Performance measurement system focus	Performance measurement system focused on delivery reliability	Performance measurement system not focused on delivery reliability	Management focus on delivery reliability also needs to be present
Quotation of feasible delivery dates	Quotation is developed taking into account load and capacity	Quotation ignores load and capacity	Quotation method must take into account load and capacity for all orders
Planning and progress control	Monitor progress of orders Focused on delivery reliability	Poor monitoring of orders Not continuously focused on delivery reliability	Quotation of feasible delivery dates is important Management focus on delivery reliability also needs to be present

Table 8.5: Characteristics of plants with high and low levels of delivery reliability.

The findings from the research suggest that high levels of delivery reliability are associated with a number of characteristics. In summary:

1) The plants that achieved high levels of delivery reliability, manufactured a low proportion of their output as customised products. If they did manufacturer some customised products they were able to reduce their impact on delivery reliability by following procedures that ensured they quoted feasible delivery dates. They also monitored the progress of customer orders, for both customised and standard products.

2) Plants that achieved high levels of delivery reliability enjoyed high levels of supplier delivery reliability. They appeared to be actively ensuring that suppliers delivery reliability was high.

3) The plants with high levels of delivery reliability did not experience high levels of demand uncertainty. However, if they had they would have been able to cope with it because they had spare capacity and the ability to change their delivery dates at the quotation stage.

4) Plants that achieved high levels of delivery reliability supplied mainly demanding customers. In order to meet the demands of these customers they quoted feasible delivery dates, and had a management team focused on delivery reliability. The focus of the management team meant that the progress control of orders was continuously carried out to ensure that orders achieved their delivery dates.

5) The plants with high levels of delivery reliability also had a number of other characteristics. They all quoted feasible delivery dates, had a performance measurement system focused on delivery reliability, had a management team focused on delivery reliability and their progress control was focused on ensuring the achievement of delivery dates.

Table 8.5 indicates that the plants with low levels of delivery reliability lacked a large number of the characteristics possessed by the plants with the high level of delivery reliability.

8.5 CONCLUSION

The research results (from the case study and survey stages) suggest that a number of variables impact delivery reliability. The main findings are as follows:

1. The research indicates that there is a positive relationship between the quotation of feasible delivery dates and delivery reliability.
2. A positive relationship was found to be present between the focus of the management team on delivery reliability and plant delivery reliability.
3. The research also identified the fact that there was a positive relationship between the focus of the performance measurement system on delivery reliability and plant delivery reliability.
4. The research found that there was a positive relationship between demanding customers and plant delivery reliability.
5. Customisation was found to be negatively related to delivery reliability. The research analysis found that as the proportion of customised products manufactured by the plant increased, so the level of delivery reliability declined.
6. Supplier delivery reliability was found to be positively related to delivery reliability. The research identified the fact that plants that enjoyed high levels of supplier delivery reliability also had high levels of delivery reliability.
7. The research found that there was a negative relationship between demand uncertainty and plant delivery reliability. The research found that plants that experienced high levels of demand uncertainty also had low levels of delivery reliability.

Part complexity was originally postulated to be related to delivery reliability. The research results indicated that there was no relationship between part complexity and delivery reliability. However, part complexity is just one type of complexity and it may be that process complexity is related to delivery reliability. The relationship between process complexity and delivery reliability needs further research.

CHAPTER NINE

CONCLUSION

9.0 INTRODUCTION

This final chapter summarises the research project, presents the main findings and evaluates their contribution to knowledge. The first section in this chapter briefly outlining the research project and the research methods used. In the next section the research results are summarised, compared to the hypotheses and propositions and then discussed. The next section outlines the contribution of the research. The penultimate section gives some recommendations as to possible areas for future research.

9.1 THE RESEARCH PROJECT

The project researched one aspect of delivery performance - delivery reliability. Delivery reliability is a critical issue for many manufacturers because it is an important factor that customers consider when making decisions about which suppliers they will purchase from. Consequently, the manufacturing strategy literature proposes that delivery reliability is a key strategic variable. Delivery reliability is a competitive priority that helps manufacturing companies win orders in the market place.

The research project was set up to investigate the factors that impact plant delivery reliability. The literature review presented in Chapter's Two and Three has indicated that the pool of empirical research specifically about the subject of delivery reliability was, as Handfield and Pannesi (1992) had found, small compared to the volume of

research into the issue of, for example, quality. This situation needed to be rectified, especially since delivery reliability was an important strategic variable.

The literature review in Chapter Two indicates that a large part of the research relating to delivery reliability sits within the area of production planning and control. The literature indicates that there are other factors which impact delivery reliability, that do not fall within the sphere of production planning and control. These other factors were: complexity, customisation, demanding customers, management focus, performance measurement focus and demand uncertainty. These other factors were covered in Chapter Three. While the literature examined in Chapter Three suggested that various factors, apart from production planning, had an influence on delivery reliability there was little in the way of empirical evidence to provide conclusive support.

Overall, research into delivery reliability has concentrated on certain areas. The research has tended to look at how single factors impact delivery reliability. While some areas have been explored in detail, others have been briefly mentioned or simply ignored. In addition, researchers have tended not to build on previous work, preferring to explore relationships in isolation. There has been no real attempt to take a more holistic view about delivery reliability and to tie all the main variables together in a more complete model of delivery reliability.

Overall, the literature reviewed in both Chapter's Two and Three tended to adopt a fragmented approach to researching the factors that impact delivery reliability. It was recognised that all the factors needed to be examined as part of a coherent model. Figure 9.1 presents the original conceptual model of plant delivery reliability that was developed, based on the literature review. The model shows the forces that are supposedly present outside and within the plant.

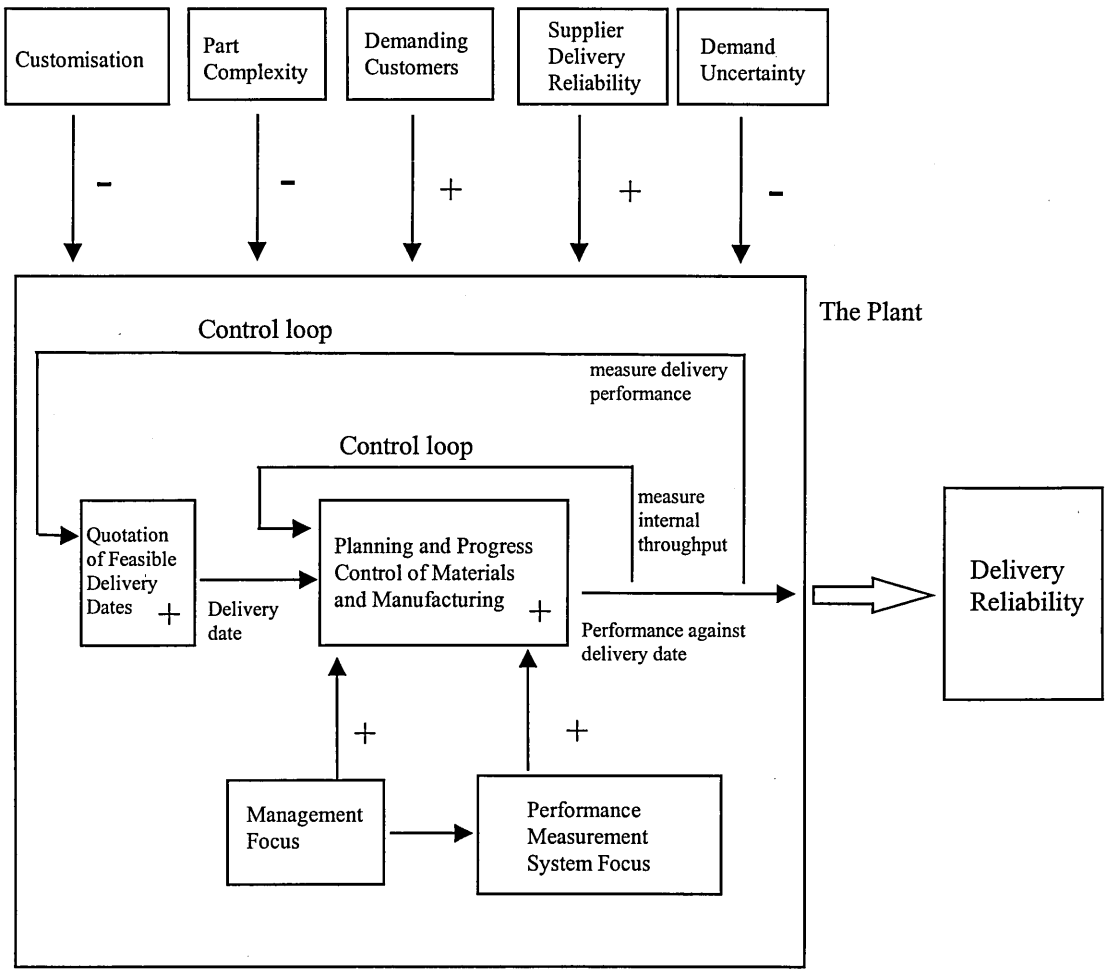

Figure 9.1 Conceptual Model of Delivery Reliability

The review of the literature also gave rise to two hypotheses and four propositions, which are presented in Table 9.1. The research investigated the relevance of the hypotheses and propositions. It also investigated the various relationships shown in the conceptual model.

No	Research Hypothesis/Proposition
H1	Plants that manufacture a low proportion of their output as customised products are likely to have a higher level of delivery reliability than those plants that manufacture a high proportion of their output as customised products.
H2	Plants that manufacture relatively complex products are likely to have lower levels of delivery reliability than plants that manufacture relatively simple products.
P1	In plants where the production planning department determines the delivery quotation, the level of delivery reliability will be high
P2	In plants where the customers have expectations of high levels of delivery reliability, the level of delivery reliability will be high
P3	In plants where the management team is predominantly focused on delivery reliability, the level of delivery reliability will be high
P4	In plants where the performance measurement system has delivery reliability as a key area of focus, levels of delivery reliability will be high

Table 9.1: Research hypotheses and propositions.

9.1.1 Research Strategy

In order to investigate the two hypotheses and the four propositions (presented in Table 9.1) it was necessary to use the survey and case study methods.

The research hypothesis and proposition to be investigated actually required a combination of research methods. At first glance the appropriate way to undertake the research was via the use of a survey, in particular hypotheses H1 and H2 could be investigated by the use of a survey. However, the four propositions required a greater in-depth investigation to be carried out, which could not be carried out via the vehicle of a survey. In order to investigate the focus of the performance measurement system,

the most appropriate approach was to interview the managers at a plant on a face-to-face basis. It would be difficult, if not impossible, to really get at the actual "focus" of the performance measurement system by simply asking for a survey questionnaire to be completed. The same was true of the focus of the management team. The case study approach is more appropriate for providing the richness and depth of analysis for identifying the interactions and explaining the outcomes in the manufacturing plant. So in order to investigate the four propositions a more qualitatively based approach was used; the four propositions would be investigated via the use of the case study technique. Consequently, the final research design utilised both the survey and a case study approach (Figure 9.2).

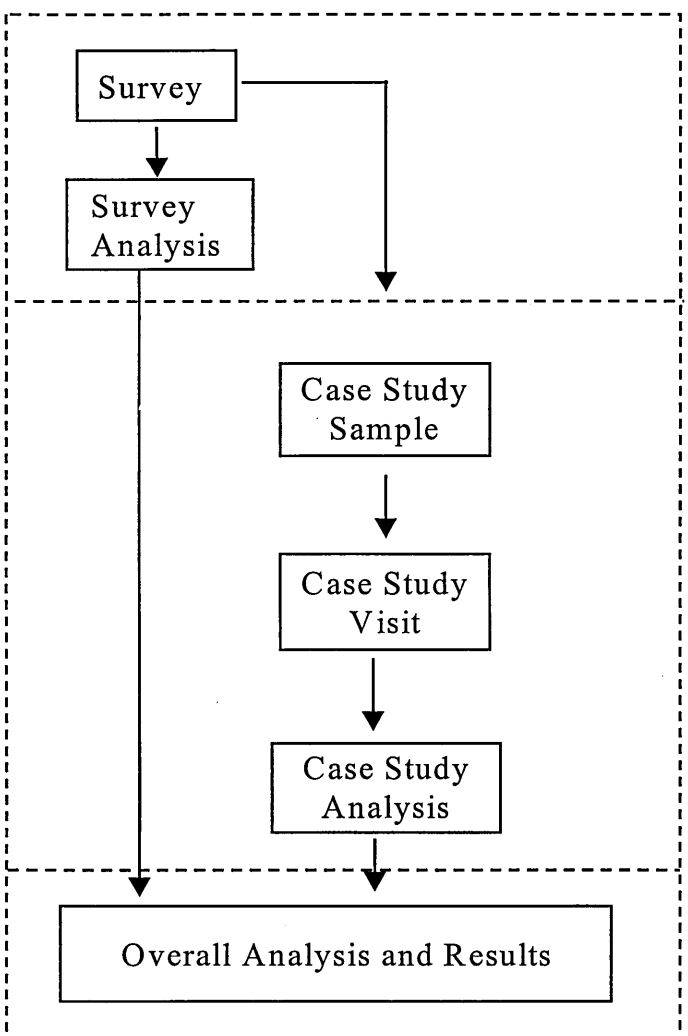

Figure 9.2: Survey and case study.

The first empirical stage of the research consisted of a survey of UK manufacturing plants. This was followed by the second stage that consisted of a series of case studies.

During the first stage, a survey of UK manufacturing plants was analysed. The questionnaire data was used to examine hypotheses H1 and H2. The second stage, involved using the plants that responded to form a sample from which the case studies could be selected.

The case study stage of the research consisted of visits to four pairs of plants (8 plants in total). These pairs were selected from the group of plants that completed the questionnaire. Each pair consisted of one plant with poor delivery reliability and one with high delivery reliability; since the questionnaire collected data about plant delivery reliability it was possible to select plants with good and poor performance. The use of a pool of responding plants allowed the author to select the appropriate pairs of plants for the case study analysis. Also, it gave me the ability to control for possible key intervening variables and so select pairs of similar plants (similar except for the level of delivery reliability). The use of this sample pool also allowed the creation of a reserve list of plants. These would be contacted should one of the pair not be prepared to allow me to include them in my research. Stage two of the research helped to determine if the propositions were correct.

The research approach adopted was a departure from the approach usually adopted by Operations Management researchers, who tend to use only one method e.g. survey. Certainly if one examines the literature relating to delivery reliability, it has tended to adopt a single approach, either the survey or the case study approach. However, in the case of this research project the use of one method would not, in itself, have effectively researched all the issues. Yin (1984) makes the valid point that different research approaches should be selected according to the research problem and can

even be combined in some situations. Kaplan and Duchan (1988) argue that the survey and case study should not be viewed as polar opposites, as is sometimes done in Operations Management research, it is possible to integrate the two methods. Combining these methods introduces both testability and context into the research. As they point out, collecting different kinds of data by different methods from different sources provides a wider range of coverage that will result in a fuller picture of the entity under study than would have been achieved other wise. Mitroff and Mason (1982), also make the point that the use of different techniques helps to produce a more holistic approach. Combining the two methods can provide a richer context basis for interpreting and validating results. The dual method adopted in this thesis helps to give a more holistic and rich view of the area being researched.

9.2 SUMMARY OF THE RESEARCH FINDINGS

The survey stage of the research examined a number of areas, in particular those relating to the hypothesis (H1 and H2).

The first hypothesis (H1) addresses the issue of customisation and its impact on delivery reliability (the results are presented in Table 9.2). The manufacturing plant that has to deal with a high proportion of customised products has a difficult job to do. For example, at the quotation stage it will be difficult to accurately quote an achievable delivery due date. The plant making standard products does not have to deal with this problem, the management knows how long it takes to make a product and so they can provide an accurate delivery quotation. The results from survey analysis show that plants where the proportion of customised products was low were also achieving high levels of delivery reliability. The results also indicated that plants where the proportion of customised products was high also had low levels of delivery reliability. The results indicate that hypothesis H1 could be accepted. However, the results are limited to the sample.

No	Hypothesis/Proposition	Method	Accepted?	Notes
H1	Plants that manufacture a low proportion of their output as customised products are likely to have a higher level of delivery reliability than those plants that manufacture a high proportion of their output as customised products.	Survey	Yes (Limited to the sample)	See section 6.2.2
H2	Plants that manufacture relatively complex products are likely to have lower levels of delivery reliability than plants that manufacture relatively simple products.	Survey	No	See section 6.2.3
P1	In plants where the production planning department determines the delivery quotation, the level of delivery reliability will be high.	Case study	Yes (Limited to the sample)	See section 7.3
P2	In plants where the customers have expectations of high levels of delivery reliability, the level of delivery reliability will be high.	Case study	Yes (Limited to the sample)	See section 7.5
P3	In plants where the management team is predominantly focused on delivery reliability, the level of delivery reliability will be high.	Case study	Yes (Limited to the sample)	See section 7.7
P4	In plants where the performance measurement system has delivery reliability as a key area of focus, levels of delivery reliability will be high.	Case study	Yes (Limited to the sample)	See section 7.8

Table 9.2: Comparison of the results against the hypotheses and the propositions.

Hypothesis H2 suggests that plants that manufacture complex products are likely to have lower levels of delivery reliability. A simple product (low product complexity) is easier to manufacture than a more complex product. With a simple product there are fewer parts to schedule. A simple product has fewer parts to procure and fewer components that have to be progressed through the production process. Generally, the task is easier and so the delivery dates are more likely to be achieved when compared

to a more complex product. However, the results from the survey analysis indicate that there is no relationship between part complexity and plant delivery reliability. The hypothesis H2 was rejected and the null hypothesis was accepted.

The case study stage of the research project examined a number of areas. In particular, it was used to examine the four propositions (outlined in Table 9.1). Table 9.2 summarises the main findings for the four propositions.

The first proposition (P1) states that where the production planning department determines the delivery quotation, the level of delivery reliability would be high. Since the production planning department has the best understanding of the capabilities of the plant and what its' current and future load is, it is in a position to quote achievable delivery dates. If another department, such as sales, was to be responsible for quoting delivery dates there is a danger that they may over commit plant capacity (if it did not consult with planning). The end result of this action will be poor delivery reliability. The results from the case study analysis indicated that the proposition was correct. The research found that at those case study plants where the production planning department determined the delivery quotation, delivery reliability was high.. While the proposition was found to be correct, these results are limited to the sample of plants investigated.

The second proposition (P2) states that for those plants where the customers have expectation of high levels of delivery reliability, the level of delivery reliability would be high. If the plant supplied mainly demanding customers it would be forced to provide them with high levels of delivery reliability. However, if the plant supplied mainly undemanding customers then there was an opportunity for the plant to have low poor delivery reliability, knowing that it would not impact future business. If problems and delays occurred in the plant the incentive to resolve them immediately was reduced in the case of the plant with undemanding customers because any delays caused by stoppages in the plant would not result in lost business. The case study

evidence identified that this proposition was correct. The plants that supplied mainly demanding customers also achieved high levels of delivery reliability. The case study evidence also uncovered the fact that it was only at the plant where the majority of the customers were demanding that the delivery reliability was high. At the plants where there were some demanding customers, delivery reliability to them was high, but to the remaining customers it was poor with the result that overall delivery reliability was low. While the proposition was found to be correct, these results are limited to the sample of plants investigated.

The third proposition (P3) suggests that in plants where the management team is focused on delivery reliability the level of delivery reliability will be high. The case study evidence pointed to the fact that the proposition was correct. The plants with high levels of delivery reliability all had management teams focused on delivering good delivery reliability; while in the case of the plants with low delivery reliability the management teams were not as focused on delivery reliability. At these plants the focus of the management team was more in the financial area. While the proposition was found to be correct, these results are limited to the sample of plants investigated.

The fourth proposition (P4) contends that in plants where the performance measurement system had delivery reliability as a key area of focus the levels of delivery reliability would be high. The performance measurement system is said to influence the actions of the employees. Therefore, if the measurement system is not focused on delivery it is likely that the employees will be influenced by the particular focus of the system (in particular the performance measures relevant to them). The case study evidence suggested that this proposition was correct. The plants with high levels of delivery reliability all had a performance measurement system focused on delivery reliability; while the majority of the plants with low delivery reliability had performance measurement systems with a predominantly financial focus. While the proposition was found to be correct, these results were limited to the sample of plants investigated.

Analysis of the survey data found that a number of other relationships were present. The analysis found that supplier delivery reliability was positively related to plant delivery reliability. As the level of supplier delivery reliability improved so the level of plant delivery reliability also improved. However, the results were limited to the sample.

Analysis of the survey data found that demand uncertainty was negatively related to plant delivery reliability. As the level of demand uncertainty increased so the level of plant delivery reliability fell. However, the results were limited to the sample.

The cases study research also uncovered a number of interesting findings. The case study research identified the fact that the way that the plants arrived at their delivery date quotation also had an impact on delivery reliability. All the plants with high delivery reliability quoted delivery dates taking into account load and capacity. However, the majority of the plants in the low group did not follow this approach, rather they tended to use standard lead times to arrive at the delivery date quotation.

The case study research also identified the fact that the plants with high levels of delivery reliability all had stable production schedules. The plants with low levels of delivery reliability tended to have schedules that were not stable.

The case study results indicate that the plants with high levels of delivery reliability continuously monitored the progress of the orders through the factory. If there were orders that looked in danger of falling behind they took remedial action to rectify the situation. This picture was not seen at the plants with poor delivery reliability.

The original conceptual model was revised in the light of the project research results. Figure 9.3 shows the revised model of plant delivery reliability.

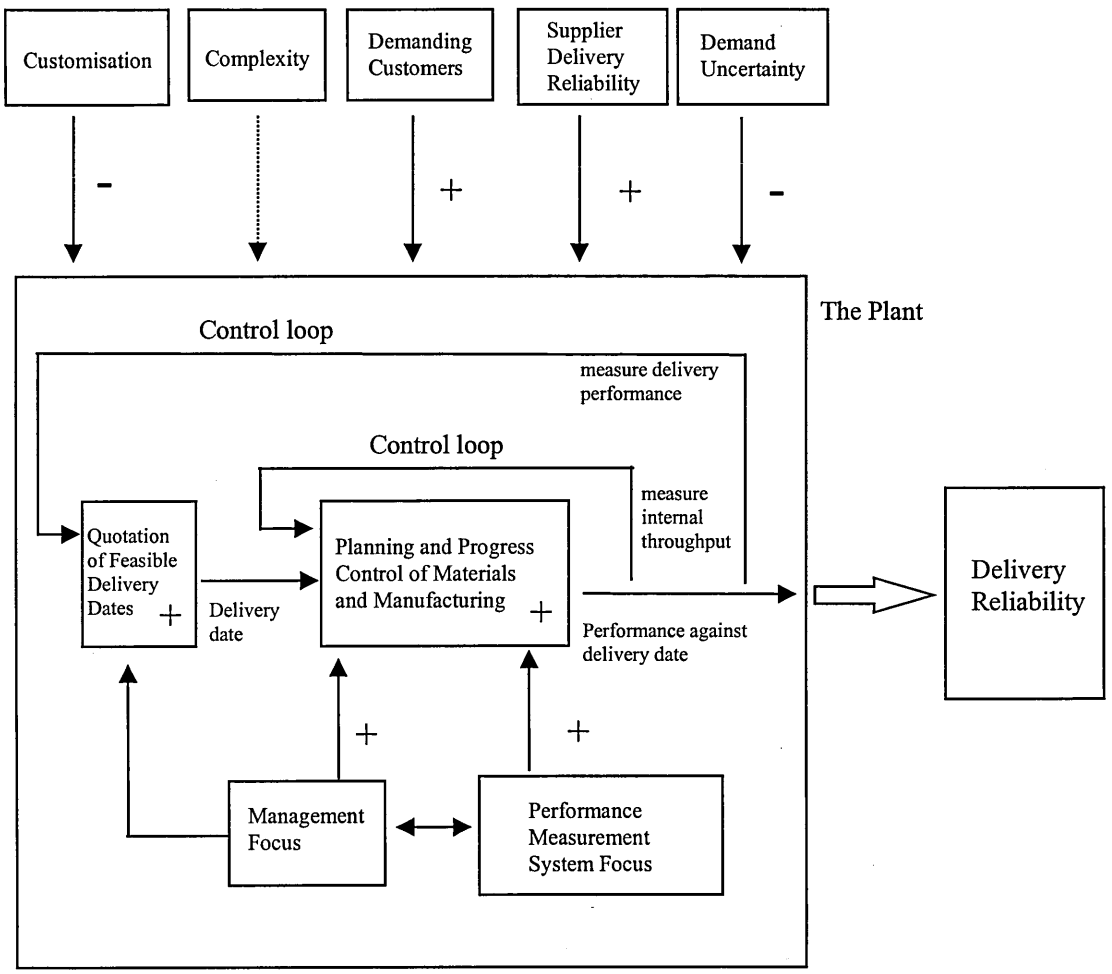

Figure 9.3: Revised conceptual model of plant delivery reliability.

9.3 CONTRIBUTION OF THE RESEARCH

While a number of writers have suggested various factors that impact delivery reliability, there has been very little empirical research carried out into the exact nature of the relationship between these factors and plant delivery reliability. The research carried out by the author has shown the extent and nature of the relationship between several factors and delivery reliability. Some of these factors have not been researched in any great depth by previous researchers.

The research outlined in this thesis has shown that:

1. Supplier delivery reliability is positively related to plant delivery reliability. The research results suggest that as supplier delivery reliability improves so does plant delivery reliability. The previous research in this area has been very limited and involved the use of the single case study method. The research outlined in this thesis has been the first to use a large survey to investigate the relationship between supplier delivery reliability and plant delivery reliability.
2. The research found that the proportion of customised products is negatively related to plant delivery reliability. The results indicate that as the proportion of customised products increases so the level of plant delivery reliability declines. The previous research in this area has been limited and involved the use of the simulation and case study method. On the other hand, the author's research has been the first to use a large survey to investigate the relationship between the proportion of customised products and plant delivery reliability.
3. The literature review highlighted that there was one area where there was no empirical research. This area was demanding customers. The current research project was able to offer empirical evidence that demanding customers are positively related to delivery reliability. The case study research found that plants that supplied mainly demanding customers had high levels of delivery reliability. The plants that supplied some or no demanding customers had low levels of plant delivery reliability.
4. The research identified that demand uncertainty was negatively related to plant delivery reliability. The research results indicate that as the level of demand uncertainty increases so plant delivery reliability declines. The research carried out by the author was the first large survey examining the relationship between demand uncertainty and plant delivery reliability.
5. A key contribution of the research was to develop and test a holistic model of delivery reliability. Very few of the researchers examining the issue have

developed or tested a model of delivery reliability. The model investigated brought together, the softer management related variables and the harder descriptive variables such as customisation and supplier delivery reliability.

Overall, the research has a valuable contribution to make since it is based on actual recorded performance data rather than being based on a manager's perceptions. Using managers' perceptions of performance should be treated with caution, since it can be optimistic and so not present a true picture of the factory's performance. This is a failing that some of the previous research suffers from.

The research made a contribution to the methodological approach that could be used in Operations Management. The approach to the research project was innovative due to the use of both the survey and case study method. The approach adopted was also unique in the way the case study sample was created. By being able to select case study plants from a large survey sample it was possible to be more precise in the selection of which plants to investigate. This approach allowed for greater control to be exercised in the case study sample selection.

9.4 LIMITATIONS OF THE RESEARCH DESIGN

There are, of course, some limitations to the current research presented in this thesis. Many of these result from the exploratory nature of the research. However, recognition of these will be of value to future researchers investigating delivery reliability. Overall the limitations can be classified into three main areas:

1. Definition of the variables
2. Construction of the model
3. Generalisability of the findings

9.4.1 Definition of the Variables

The way some of the variables in the model were measured did have limitations, for example customisation. The approach used to measure customisation did not allow for a differentiation to be made between a customised product that required a few minor customer specific parts to be produced (e.g. external mountings or casing) and one that required a lot of customer specific parts to be manufactured. Therefore the strength of the relationship between customisation and delivery reliability may have been either under or overstated.

There was also a limitation with regard to the way demand uncertainty was measured. The major limitation of the type of scale used to measure demand uncertainty is that the distances between each of the steps of the scale may not be the same for each respondent. The distance between a 4 and a 5 for one respondent may be the same as the distance between 3 and 5 for another. So the scale is not giving a totally accurate measure of the uncertainty faced by the manufacturing plants surveyed.

9.4.2 Construction of the Model

One omission from the model was that of the impact of volume. It is highly likely that the volume of demand that an operation must deal with will have an impact upon its delivery reliability. For example, a plant that has to deal with high volume products may have a complicated production planning task to deal with. Consequently it may be difficult to quote feasible delivery dates. In addition, the production control tasks are more difficult when co-ordinating the multiplicity of batch quantities required when producing some products in large volumes. Therefore any future research on delivery reliability should consider the influence of volume upon delivery performance.

The model was developed based on previous research publications on delivery reliability. This could have been complemented by investigating the practitioners'

assessment of the factors that affect delivery reliability. Discussions with them about what they considered to be the variables that influenced delivery reliability could have been compared with previous research findings in order to design the research model.

Overall, the research examines the plants internal delivery reliability, what it does not examine is delivery to the customer's premises. This is an issue that needs to be explored. The view of the plant's delivery reliability by the customer should be examined alongside what the plant considered its own delivery performance to be.

9.4.3 Generalisability of the Findings

The findings from the survey phase of the research are limited to the sample surveyed. This is because the sampling approach used in the survey research was purposive. Such an approach was adopted because of the need to collect data from plants that measure delivery reliability and predominantly make-to-order. To obtain such a sample would have been difficult and expensive, hence the use of date taken from the plants that entered the Best Factory Awards.

The findings from the case study phase of the research are strictly speaking limited to the plants surveyed. Further research should be carried out extending the case study to cover other industrial sectors. It would be appropriate to examine continuous flow types of plants.

9.5 IMPLICATIONS OF THE RESEARCH

Chapter One showed the importance of delivery reliability for manufacturing companies because it was an important factor that customers considered when making decisions about which suppliers to buy from. Therefore, the results have some implications for managers. This is probably true despite the limitations of the research design and the limited extent to which the findings could be generalised.

9.5.1 Implications for the Practitioner

The results of the research had several implications for the practitioner. The research suggested that if the plant management wants to achieve high levels of delivery reliability they will have to ensure that supplier delivery reliability is also high. Management will also need to be aware that making high proportions of customised products may not be compatible with trying to also have very high levels of delivery reliability. The research also indicates that to achieve high levels of delivery reliability the plant management will need to ensure that feasible delivery dates are quoted. In particular during the process of quoting the delivery date load and capacity should be taken into consideration. The research also indicates that to achieve high levels of delivery reliability the management and the performance measurement system will need to be focused on delivery reliability.

The survey evidence from New & Myers (1986) and New & Szwejczewski (1995) suggests that the delivery reliability performance of UK manufacturing organisations has improved over the last 25 years (see Section 1.3.2). While the performance of UK plants has certainly improved, it is interesting to note that many plants do not achieve a performance greater than 99% (only 19.6% of the plants surveyed achieved this level of performance - see Table 6.3). So why is this the case? The model offers an answer to this question. Plants that do not have the internal control procedures indicated in the model are likely to under perform at delivery reliability. So, for example, plants that do not quote feasible delivery dates are more likely to suffer from poor delivery reliability. Also, plants that supply mainly demanding customers are likely to be driven to have high levels of delivery reliability. Since not all plants supply mainly demanding customers, this driver is missing and consequently poor delivery reliability may be the result.

While a plant can try to get the internal elements of the model right (i.e. have a management team focused on delivery etc.), there is one external element that is difficult to control. That external element is supplier delivery reliability, a plant may be in a situation where it does not possess buying power over its suppliers; it may not be able to get high levels of delivery reliability from its suppliers. It may be forced to compensate for their poor delivery reliability and consequently, not be able to achieve high levels of delivery reliability at the least cost to itself.

However, there is also the fact that some plants may not want to improve their delivery reliability because they feel that they are already achieving satisfactory levels of performance. At one of the case study plants (with low delivery reliability) the Plant Director was quite happy with the plants performance. He had a target of 95% delivery reliability and was just short of hitting it. There is therefore variability in what is deemed to be an acceptable level of delivery reliability by senior production management.

So, overall there are both internal and external reasons why not all manufacturing plants achieve more than 99% delivery reliability.

9.5.2 Implications for the Researcher

The research also has several implications for the Operations Management researcher looking into delivery reliability. The results from the survey and the case study stages show the diverse range of factors that influence delivery reliability. Previous researchers have normally focused on the relationship between single factors and delivery reliability. The current research has contributed by demonstrating the complexity and the need to look at the full range of factors. The challenge for future researchers will be to more fully understand the interaction between factors and how delivery reliability can be optimised in difficult circumstances (e.g. for plants producing a high proportion of customised products).

One key result of the research is that supplying demanding customers is associated with achieving high levels of delivery reliability. They appear to be one of the driving forces behind plants achieving high levels of delivery reliability. Demanding customers may impact other areas of plant performance This is an issue that warrants further investigation.

The research showed that the management focus on delivery reliability was associated with high levels of delivery reliability. This should be explored further and it could be that if managers invest more time in this area, significant improvements in performance can be achieved.

The results of the research project point to the role that the softer variables (such as management focus) have in helping to achieve high levels of delivery reliability. The Operations Management researcher should pay more attention to them when carrying out future research.

While the research examined the impact of customisation on delivery reliability the measure used did not give a totally accurate measurement of customisation. It may be prudent to investigate further the impact of customisation by developing a more appropriate measure. This could help to add extra support to the current research findings.

The research did not examine the impact of the volume of production the plants had to deal with. The impact of volume should be considered in any further research that is carried out into delivery reliability.

9.6 NEW AREAS FOR RESEARCH

The research presented in this thesis provides the foundation for a variety of future research projects. These could build on the research presented in this thesis.

The research has shown the impact of demanding customers on plant delivery reliability. However, the results were based on eight case studies in two industry sectors - engineering and electronics. The research could be extended via the use of case studies to examine the impact of demanding customers in other industry sectors such as injection moulding or packaging. The extension of case studies to other industry sectors could also help to examine the impact of some of the other variables, such as the focus of the management and the performance measurement system, on plant delivery reliability.

Future research should look at the relationship between process complexity and delivery reliability, an area that was not explored in the current project. Also, any future research carried out should move beyond the exploratory stage and use a random sampling approach.

9.7 SUMMARY

This thesis describes the research into the issue of plant delivery reliability. In particular it covers an examination of the relationship between part complexity, customisation, management focus, performance measurement system focus and plant delivery reliability.

The research started with a literature review of the factors that impact delivery reliability. The literature review gave rise to a number of research questions. These research questions led to the development of two hypotheses and four propositions. The hypotheses and propositions were investigated using the survey and case study

methods. A holistic model of plant delivery reliability was also developed and elements of it were examined as part of the research project.

The project involved two empirical stage. Firstly, a large survey of UK manufacturing plants was used. This was followed by the use of a series of case studies. The survey was used to determine if the hypotheses could be accepted. The plants that were part of the survey were used to form a sample from which the case study plants could be selected.

The case study stage of the research used a matched sample approach. Four pairs of plants were selected from the plants that completed the survey questionnaire. Each pair of plants consisted of two fairly similar plants, except that one had poor delivery reliability while the other had good performance. Using the case study approach it was possible to investigate the four propositions.

The research made a number of contributions. Firstly the research found a significant negative relationship existed between the proportion of customised products and delivery reliability. The results indicate that as the proportion of customised products increases so the level of plant delivery reliability declines. Secondly the research was able to offer empirical evidence that demanding customers are positively related to delivery reliability. The research research indicate that plants that supplied mainly demanding customers had high levels of delivery reliability. Whilst those plants that supplied some or no demanding customers had low levels of plant delivery reliability. The research also found that supplier delivery reliability was positively related to plant delivery reliability. The results suggested that as supplier delivery reliability improves so does plant delivery reliability.

The research identified that the focus of the management on delivery reliability was related to the level of delivery reliability. Plants where the management team was focused on delivery reliability also had high levels of delivery reliability. The focus of

the performance measurement system used in the plant was also found to be related to the level of delivery reliability. Plants that had a performance measurement system focused on delivery reliability also had high levels of delivery reliability. The level of market demand uncertainty appeared to be related to delivery reliability, and plants that experienced high levels of uncertainty also had low levels of delivery reliability. The research results also helped to provide evidence for the validity of most of the components of the original holistic model of delivery reliability.

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APPENDIX A

ALL QUESTIONS RELATE TO THE SINGLE PLANT TO BE AUDITED EXCEPT WHERE SPECIFIED OTHERWISE

A: THE PLANT PROFILE

A1 Is the plant owned by (Please tick one box only)

A Publicly Quoted UK Parent Company	☐	1
A Privately Owned UK Parent Company	☐	2
A Continental European Parent Company	☐	3
A Japanese Parent Company	☐	4
A US Parent Company	☐	5
Other Foreign Parent Company	☐	6
Joint UK/Foreign Parent Company	☐	7 1

A2. How many plants does the parent company control worldwide?
(Please tick one box only)

1 only	☐	1
2	☐	2
3	☐	3
4	☐	4
5	☐	5
6 - 10	☐	6
11 - 20	☐	7
more than 20	☐	8 2

A3. Does your TOTAL number of COMPANY employees exceed 500?
(including all plants, holding company employees etc.)

Yes ☐ 1 No ☐ 2 3

A4. What is the total area of the plant buildings?

Square Feet ☐ Or Square Metres ☐ 4

B: NATURE OF MANUFACTURING OPERATIONS

B1. What proportion of the plant's output (at manufacturing cost) falls into these four categories (a,b,c,d below):

(a) Sales Catalogue item	%	5

For what proportion of this output is the customer lead time determined by:

1. The Customer	%	6
2. Yourself as supplier	%	7
3. Negotiation	%	
	100%	

(b) Sales Catalogue with Customer Choice Options	%	8

For what proportion of this output is the customer lead time determined by:

1. The Customer	%	9
2. Yourself as supplier	%	10
3. Negotiation	%	
	100%	

(c) Customer specific design to repeat orders	%	11

For what proportion of this output is the customer lead time determined by:

1.	The Customer	%	12
2.	Yourself as supplier	%	13
3.	Negotiation	%	
		100%	

(d) Unique Customer specific design	%	14

For what proportion of this output is the customer lead time determined by:

1.	The Customer	%	15
2.	Yourself as supplier	%	16
3.	Negotiation	%	
		100%	

Total (a) + (b) + (c) + (d) = 100%

B2. What proportion of the plant's output (at manufacturing cost) falls into the following categories:

Capital Goods	(equipment used by other businesses as capital assets)	%	17
Intermediate Goods	(components, supplies etc. used by other businesses to produce their products)	%	18
Consumer Goods	(products for sale to the user, general public)	%	19
		100%	

B3 Complexity Factors

B3.(a) How many different item records are currently 'live' (in use) within the plant?

At product level (as sold to customers)		20
At manufactured component, bulk intermediate or sub-assembly level (do not include finished products or raw materials)		21
At bought out component or sub-assembly level (as purchased from suppliers but not including raw materials)		22
At purchased raw material level for processing by yourselves		23

B3.(b) How many different manufactured components, purchased items or purchased assemblies are there in the product which has the largest output (at manufacturing cost) in the plant? 24

B3.(c) In relation to all products produced in the plant over the last year:

How many products were in continuous production in the plant? (runners)		25
How many different product types (of known design) were produced intermittently/from time to time in the plant? (repeaters)		26

How many different product types (of initially unknown design) were produced in the course of the year in the plant? | | 27

B4. Manufacturing lead times and customer delivery lead times
(N.B. 1 week = 7 days is assumed)
We have separated manufacturing lead times into 3 stages:

1. Material procurement	2. Component or intermediate bulk manufacture	3. Final assembly or packaging
e.g: External purchasing of • Raw materials • Components • Ingredients • Packaging	e.g: • Individual component production • Bulk product manufacture pre-packaging • Piece part knitting/cutting	e.g: • Mechanical assembly • Food packaging • Garment making up

For the product which has the largest output (at manufacturing cost) in the plant:

B4. (a) What is the planned procurement lead time for the main (or most significantly constraining) bought out item/material: | Days | 28

B4. (b) Answer this section if as part of the manufacturing lead time you manufacture components, intermediate or bulk products.

(i) What is the planned component (or intermediate/bulk product) manufacturing lead time for:

The shortest manufacturing lead time	Days	29
The average manufacturing lead time	Days	30
The longest significant manufacturing lead time	Days	31

(ii) For the average (or typical) component (or intermediate) given above: what is the actual processing time (i.e. time in/on a machine or being hand processed) for the normal production batch quantity of the item? This time should represent the minimum elapsed time in which the batch could be manufactured in an empty factory without ANY queuing, waiting or transport time (It will usually be close to the standard hour content of the batch).

Processing time for the Average lead time item | Hours | 32

(iii) How many hours per week does the component or bulk manufacture part of the plant normally work?
e.g.: 5 days x 8hrs/day = 40 hours/week | Hours per week | 33

B4.(c) Answer this question if as part of the manufacturing lead time you carry out assembly or packaging operations.
(i) What is the planned assembly (or final packing) lead time for:

The average assembly lead time item	Days	34
The longest significant assembly lead time item	Days	35

B5. What are the quoted Customer Delivery lead times over all products produced:

The shortest customer lead time quoted	Days	36
The average customer lead time quoted	Days	37
The longest customer lead time quoted	Days	38

B6. What proportion of the plant's total output (at manufacturing cost) is supplied to customers (in this question manufacturing lead time is the total component/intermediate and final assembly/packaging lead time):

Off the shelf (ex-finished goods stock)	(A)	%	39
On a quoted lead time shorter than the actual manufacturing lead time (i.e. assemble-to-order, pack-to-order)	(B)	%	40
On a quoted lead time equal to or longer than the actual manufacturing lead time (through engineering design work or backlog for example)	(C)	%	41
Total output of plant	(A)+(B)+(C)=	100%	

B7. For the proportion of output supplied on a quoted lead time (category B and/or C above):

B7.(a) For what proportion of the output supplied on a quoted delivery date is this date mainly determined by:

Customer requirements	%	42
Capacity/scheduling constraints in your plant	%	43
Material availability in the supply chain	%	44
Design availability	%	45
Total output supplied on a quoted lead time	100%	

B7. (b) What does a quoted delivery date to a customer (supplied on a quoted lead time) mean in your plant?

	% of output	
Specific week ending date	%	46
Specific day date	%	47
Specific time(s) of day (delivery slot)	%	48
Other (please specify)	%	49
	100%	

B7. (c) What are the major factors which facilitate good deliveryperformance in your plant: (Please rank from 1-7, where 1=most importantand 7=least important)

	Rank (1-7)	
Excess capacity		50
A reliable supply chain		51
Workforce flexibility		52
Reliable processes		53
Quick changeovers		54
Responsive planning and control system		55
Other (please specify)		56

B8. Set-up and Changeover Times

How long does a typical changeover between products or batches take? e.g: time to reset line, tools/dies, clean and recharge etc.

	Minutes			
	Shortest	Average	Longest	
In Component/Intermediate Manufacture				57,58,59
In Assembly/Packaging				60,61,62

B9.(a) Number of customers
How many different customers does your plant ship to:

	Number	
Third party customers	%	63
Your own company distribution points	%	64
Other plants within your own company	%	65

B9.(b) What percentage of turnover by value do they represent?

	% of turnover	
Third party customers	%	66
Your own company distribution points	%	67
Other plants within your own company	%	68

B10.(a) Number of suppliers
How many suppliers do/did you have for manufacturing purposes:

	Number	
Currently		69
In 1994		70
In 1992		71

B10(b) What proportion of your suppliers currently deliver to you:

Daily	%	72
Twice weekly	%	73
Weekly	%	74
Monthly	%	75
Less frequently than monthly	%	76
	100%	

B10.(c) Do you formally measure the delivery performance of your suppliers?

Yes ☐ 1 No ☐ 2 77

If yes what is the current overall delivery performance?

	% on time	78

C: Cost Structure

C1. The Manufacturing Cost Structure: Please give the breakdown for your most recently completed budget year, giving a figure for each separate section wherever possible:

Tick the appropriate box to indicate the units in which your cost structure is expressed below:
(Tick one): £000's ☐ £millions ☐

Bought out raw materials	(a)		79
Purchased components, assemblies & packaging	(b)		80
Energy costs	(c)		81
Bought out services (rent, rates, equipment hire etc.)	(d)		82
Direct labour	(e)		83
Indirect factory labour	(f)		84
All other labour (including staff and managerial)	(g)		85
Depreciation charges	(h)		86
Other	(i)		87
Total value of manufacturing output at cost (sum of (a) to (i)			88

Other costs associated with this output (design, marketing etc.)		89
Net profit before Interest and Tax		90
Sales Value of this output		91

Amount owing to your suppliers at the end of the most recently completed budget year		92

Total value of manufacturing output at cost expected:		
- in current budget year		93
- in next budget year		94

C2. How has the unit cost for the product which has the largest output (at manufacturing cost) changed over the last two years:

Unit cost has: (please tick one box only)

Decreased by	More than 20%	☐	1	
	10 - 19%	☐	2	
	5 - 9%	☐	3	
	Less than 5%	☐	4	
Remained the same		☐	5	
Increased by	Less than 5%	☐	6	
	5 - 9%	☐	7	
	10 - 19%	☐	8	
	More than 20%	☐	9	95

D: INVENTORY PROFILE

Please give details relating to the most recent complete budget year:

D1(a) What was the average level of inventory investment for the following five categories:

Tick the appropriate box to indicate the units in which your average inventory value is expressed below:

Tick one: £000's ☐

£millions ☐

	£ Average value over year	Weeks of Usage	
Raw Materials			96,97
Bought out Components and Assemblies etc.			98,99
Work in Process including: • Components/intermediates in manufacture • Finished components or intermediates awaiting assembly or packing • Assembly/Packing			100,101
Finished Goods Ready for Sale			102,103

D1.(b) If your business is highly seasonal what degree of deviation + or - is there around the above figures

+		
-	%	104

D2. How has this inventory profile changed over the last two years:

Average Inventory has: (Please tick one box only)

Decreased by	More than 50%	☐	1	
	25 - 50%	☐	2	
	10 - 24%	☐	3	
	Less than 10%	☐	4	
Remained the same		☐	5	
Increased by	Less than 10%	☐	6	
	10 - 24%	☐	7	
	25 - 50%	☐	8	
	More than 50%	☐	9	105

E: EMPLOYEE PROFILE

E1. Current Profile across the Plant (in terms of Full Time Equivalent employees, include all temporary or contract employees):

			No. of FTE's	
Plant Management & Supervisory		(a)		106
Technical Support	Manufacturing, Industrial and/or Process Engineering, support staff	(b)		107
Materials Management	Planning, Scheduling, Order Processing Production and Inventory Control, Purchasing, Warehouse Operations	(c)		108
Quality Management	Quality Control, Management and Audit	(d)		109
Other Indirect Support	(please specify here)	(e)		110
Direct Value Adding Production Employees	Component or Intermediate Manufacturing, Assembly and/or packaging	(f)		111
Total Production Related (a+b+c+d+e+f=g)		(g)		112
Design	Product Design and Development			113
Other	All other support activities including: Personnel Accounting etc.			114
Total Employees				115

E2. What proportion of Direct Value Adding Production Employees (see f above) are temporary or contract emplyees? ____ % 116

E3. For Total Production related employees (see g above):

EMPLOYEE PROFILE		Numbers of employees	
(a) By Age	Under 30 yrs	%	117
	30 - 40	%	118
	41 - 50	%	119
	Over 50	%	120

(b) Average Length of Service:	Years	121
(c) Average Rate of Absenteeism:	%	122
(d) Average Annual Turnover Rate:	%	123

E3. (e) Over the last two years Total Employee numbers have: (Please tick one box only)

Decreased by more than 20%	☐ 1	
Decreased by less than 20%	☐ 2	
Remained static	☐ 3	
Increased by less than 20%	☐ 4	
Increased by more than 20%	☐ 5	124

E4. What is the average number of days training received per employee per year?

	On job training	Off job training		
New starters			Days	125,126
Existing employees			Days	127,128

E5. What percentage of the production employees can carry out more than 50% of the production tasks in their area ☐ % 129

E6. (a) Employee Involvement Do you run an employee suggestion scheme?

Yes ☐ 1 No ☐ 2 130

If yes what was the number of suggestions per employee per annum in 1995 ☐ 131

What type of reward was offered as part of the scheme (tick one box):

Substantial financial reward	☐ 1	
Small financial award	☐ 2	
Token reward only	☐ 3	
No reward	☐ 4	132

E6. (b) Are Production Employees involved in formal Problem Solving Groups?

Yes ☐ 1 No ☐ 2 133

If yes, what proportion of production employees are involved as a percentage of total production employees ☐ % 134

Are groups (tick one box):

Temporary	☐ 1	
Permanent	☐ 2	
Both	☐ 3	135

How frequently do they meet (tick one box)

Daily	☐ 1	
2-3 times per week	☐ 2	
Weekly	☐ 3	
Less frequently	☐ 4	136

Are group leaders (Tick one box)

Appointed by management	☐ 1	
Elected by group	☐ 2	
Rotated within group	☐ 3	
Other	☐ 4	137

F: PRODUCT INNOVATION

A significantly new product is one which the plant has not made previously and which represents more than a simple change of material, colour or design variant. For example, in garment manufacturing a pair of trousers made in a new material would not be regarded as significant. However, if the trouser manufacturer started making overcoats this would be regarded as significant for the plant.

F1. How long does it typically take to bring significant product innovation to market (from start of detail design to market launch)? ____ months 138

F2.(a) How many significantly new products (not including material or minor model changes) have you launched in the last 5 years? ____ months 139

F2.(b) Of these new products how many would you regard as:

Extensions to existing product range(s)		140
Totally new (to plant) product range(s)		141
Other (please specify)		142

F2.(c) How many significantly new products (not including material or minor model changes) do you expect to launch in the next 5 years? ____ 143

F3. For those products made to a unique customer specific design,

What is the typical level of (please circle one of the numbers on the scale for each item)?

	Low				High	
Technological novelty	1	2	3	4	5	144
Specific Applications Engineering	1	2	3	4	5	145
Number of drawing changes required	1	2	3	4	5	146
Use of new materials	1	2	3	4	5	147

G: MANAGEMENT INFORMATION

Is this factor measured formally on a regular basis (Tick Yes or No for each factor). If yes then please give current levels unless otherwise requested:

G1 Output Volume Yes ☐ 1 No ☐ 2 Output per Week ☐ 148,149,150
Units of Measurement ☐

G2. Production schedule adherence Yes ☐ 1 No ☐ 2 % Schedule Adherence in 1994 ☐ current ☐ 151,152,153

G3. Delivery Performance

(a) Ex-stock Availability (For items on ex-stock supply) Yes ☐ 1 No ☐ 2 N/A ☐ 3 Service Level ex-finished stock in 1994 ☐ current ☐ 154,155,156

(b) Due-date Reliability (For items on quoted lead times) Yes ☐ 1 No ☐ 2 N/A ☐ 3 % Delivery 'on time' in 1994 ☐ % current ☐ % 157,158,159

G4. Inventory Record Accuracy Yes ☐ 1 No ☐ 2 % Correct ☐ % 160,161

G5. Scrap or Yield Loss Rate Yes ☐ 1 No ☐ 2 % Scrap or % below ideal yield rate in 1994 ☐ current ☐ 162,163,164

G6. Time spent on Rework/Reprocessing Yes ☐ 1 No ☐ 2 % Capacity used for Reprocessing ☐ % 165,166

G7. Time spent on Setting/Changeover Yes ☐ 1 No ☐ 2 % Capacity used for Changeover ☐ % 167,168

G8. Customer returns (or complaints) for quality reasons Yes ☐ 1 No ☐ 2 % Returns in 1994 ☐ % current ☐ % 169,170,171

F9. First time pass rate at final test Yes ☐ 1 No ☐ 2 Current ☐ % 172,173

H: MARKET POSITIONING

For the product group with the largest output (at manufacturing cost) in the plant:

H1. Please rank the following criteria in order of relative importance to the customer:
(1 = Greatest Importance, 7 = Least Importance)

	Rank (1 to 7)	
Quoted Delivery Lead Time		174
Reliability of Delivery Date or Service Level		175
Product Features or Performance		176
Technical Support		177
After Sales Service		178
Brand Image/Reputation		179
Price		180

H2. What relative emphasis do your auditable plans for the next two years place on each of the following areas in order to give your plant a competitive advantage? Please rank the areas in order of priority (1 = Great Importance, 7 = Least Importance)

	Rank (1 to 7)	
Rapid Product Design Change		181
Consistent Quality		182
Short Delivery Lead Times		183
Dependable Delivery Dates		184
After Sales Service		185
Improved Product Performance		186
Manufacturing Cost Reduction		187

H3. Over the next six months what is the degree of unpredictability for the following (please circle one number for each)

	Highly Predictable				Highly Unpredictable	
Customer demand levels	1	2	3	4	5	188
Competitor activity	1	2	3	4	5	189
Raw material prices	1	2	3	4	5	190
Raw material or component availability	1	2	3	4	5	191
Legislative environment	1	2	3	4	5	192

H4. The General Characteristics of your Plant:

Please score your plant out of 10 (10=Perfect, 1=Poor) on each of the following characteristics. Your score should reflect your view of your own plant in relation to what you think should be possible in your industry:

1. The plant is clean, tidy and uncluttered. A place for everything and everything in its place.		193
2. Plant performance is based upon the dependability of the process (not on output alone). Do the performance measures used relate to whether you did exactly what you said you would do in terms of quantity and timing?		194
3. The Process documentation is accurate, detailed and used. If a competent operator did it according to the process specification would it work?		195
4. Process Engineering is regarded as important to performance. Continuous effort is focused on process improvement.		196
5. Material moves very quickly through the process. Short throughput or lead times are important.		197
6. Employees have very broad work task definitions. High levels of labour flexibility across skill ranges.		198
7. All employees are committed to continuous improvement on all performance factors.		199
8. Training and competence is emphasised throughout the plant. High levels of cross training are present, skill matrices monitored.		200
9. Labour is primarily regarded as a source of brainpower not just muscle power. All the labour force is involved in process improvement.		201
10. Employees accept that change is a way of life and that learning "on the run" is the norm.		202
Total Score (Maximum 100)		

H5.(a) Please give a brief description of the kinds of products which the plant manufactures e.g. plastic components for automotive industry, chemicals for pigment manufacture, domestic washing machines.

Office Use Only	

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H5.(b) Please give a brief description of the main manufacturing processes involved.

Primary Processing Stages
eg. Component machining, ingredient mixing, distillation, bulk chemical synthesis, fabric manufacture and processing, printed circuit board assembly.

Secondary Processing Stages
e.g. Product assembly, product packaging, cutting and finishing.

H6. Please state briefly the areas in which you think your plant is particularly strong and indicate any major improvements which have been made over the last two years.

H7.(a) When manufacturing investment decisions are made do you differentiate between the rate of return required for Operational Investment (eg. buying a new machine or replacing an existing one) and Strategic Investment (eg. major capital investment in new technology or a new plant)?

Yes (we do differentiate)	No (we do not differentiate)	
☐ 1	☐ 2	204

H7.(b) What was the required rate of return for the two types of investment in the year 1995?

If you use an Internal Rate of Return criterion:

IRR for Operational Investment	%	205
IRR for Strategic Investment	%	206

If you use a Payback Period criterion:

Payback for Operational Investment	months	207
Payback for Strategic Investment	months	208