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**IMPACT OF CLOSE RELATIONSHIP WITH SUPPLIERS
ON A FIRM'S MANUFACTURING FLEXIBILITY**

by

Khalil Viraney, B.Comm.,1990

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of
Master of Management Studies

School of Business
Carleton University
Ottawa, Ontario

December 1995
Khalil Viraney
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**IMPACT OF CLOSE RELATIONSHIP WITH SUPPLIERS ON A
FIRM'S MANUFACTURING FLEXIBILITY**

submitted by Khalil N. Viraney, B.Comm. (1990)
in partial fulfilment of the requirements for
the degree of **Master of Management Studies**

A handwritten signature in cursive script, appearing to read "Vinod Kumar", written over a horizontal line.

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(Thesis Co-supervisor)

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Dr. Siva Pal
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Director
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January 19, 1996

ABSTRACT

Increasing competitiveness, rapidly changing customer tastes and shortening product life cycles have forced manufacturers to produce a greater variety of products at competitive prices. Greater variety at lower costs demands flexibility.

Among many factors, a close relationship between manufacturers and suppliers is said to play an important role in contributing to flexibility. This study examines the level of affiliation between manufacturers and suppliers in four important areas: information sharing, joint product development, supplier training, and quality improvement programs. An instrument has been constructed to measure these four dimensions along with flexibility related questions to test the hypothesis regarding managers' perception of the relationship's impact on manufacturing flexibility. Purchasing and production managers of firms in the high-tech industry have been interviewed face to face.

The data show a positive relationship between the four dimensions and manufacturing flexibility. The effect was found to be quite strong in the cases of relationship characterised by a high degree of information sharing, and presence of quality and continuous improvement programs. The overall conclusion of the study is that greater cooperation with suppliers can provide significant benefits to the manufacturer.

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CHAPTER 1

INTRODUCTION

Since the early 1960's cost and quality have been considered the most dominant factors for achieving success. But in the 80's flexibility drew attention as the focus of competition in the new manufacturing environment (Ferdows et al., 1986). Cost and quality remained important, but it was recognized that a company also needs greater flexibility in order to compete in the global market of increasing product variety and shorter product life cycles.

Mass production methods were once the most efficient and economical. However, with the advance of technology, *economies of scale*, producing cost advantages, is challenged by *economies of scope* - the advantage gained with flexibility, by spreading the cost over a variety of products.

In today's environment of volatile markets, intense competition, rapidly changing tastes, short product life cycles, broad product variety, and rising costs due to the higher cost of capital and materials (Hahn et al., 1986), the ability to vary the basic product is likely to prove to be an essential element of industrial survival. In order to increase product variety without increasing costs substantially, a firm requires enhanced manufacturing capability. One of the ways of achieving this objective is through greater manufacturing flexibility. Flexibility is the key to enjoy economies of scope in the new manufacturing environment and to successfully face the time-based competition of the

1990's (Stalk, 1990).

Flexibility is the ability to change, or react to changing circumstances, with little penalty in time, effort, cost or performance (Upton, 1993). It is influenced by a myriad of variables, from supplier to workforce, from type of machinery to their maintenance.

Researchers (Buzacott, 1982; Gerwin, 1987; Slack, 1984; Brown et al., 1984; Carter, 1986 and others) have identified many dimensions of flexibility. Despite the lack of agreement (Dixon, 1992), the effort has led to a better understanding of the concept of flexibility, allowing a better platform on which to base the research on flexibility (Suarez et al., 1991; Upton, 1993).

The multi-dimensional concept of flexibility requires an understanding of how and to what extent each of the factors affect flexibility. Furthermore, thorough understanding requires flexibility measures for testing hypotheses about the relationships between many factors and the different dimensions of flexibility they affect. Such an understanding is crucial, for the managers must know how the factors could be controlled to influence manufacturing activities and provide the required flexibility (Dixon, 1992).

A number of flexibility measures have been proposed (for example Kumar, 1987; Dixon, 1992; and Upton, 1994). Many of these approaches (Brown et al., 1984; Falkner, 1986; Barad and Sipper, 1988) have concentrated on flexibility delivered by automated manufacturing technologies (AMT) where the flexibility is much more feasible to evaluate. However, little has been done to make these measures operational, especially in cases of manufacturing flexibility due to factors other than AMTs (Kumar, 1987; Brill and Mandelbaum, 1989).

Manufacturer-supplier (M-S) relationship and its impact on different types of flexibility have been mentioned often in several contexts (Manoochehri, 1984; Ansari & MoJarress, 1988; Magnet, 1994) but rarely studied. Some exceptions have concentrated on the different types of purchasing relationships, their potential benefits and changes that are required in a firm's operating practices to successfully develop different supplier relationships (Ellram, 1991). However, there has been no study on the impact of a better M-S relationship on manufacturing flexibility (*from now on referred to as flexibility*). This relationship seems to have been undergoing vast changes in the last decade and deserves to be studied seriously.

In the past, supplier contracts were short term; there were numerous suppliers, and competition was solely price-based; but now "contracts are increasingly long term, sole sourcing is becoming more common, and competition is based on quality, delivery, engineering as well as price" (Helper 1991, p.15). These changes are said to play an important role in influencing the flexibility of a firm, and provide the focus of the present exploration of the links between M-S relationship and flexibility.

This thesis, thus, explores the impact of the relationship between manufacturer and supplier on the former's manufacturing flexibility. The term *relationship* refers to the nature of affiliation between the manufacturer and supplier with respect to information sharing, joint product development, supplier training and quality improvement programs.

Information is a vital link between manufacturers and suppliers. Manufacturers' requirements from a supplier can be fulfilled only through a significant amount of communication between the two parties in terms of purchase orders, specifications and

account reconciliations. Extensive communication includes a number of other activities between manufacturers and suppliers such as sharing of production schedules, exchanging technical and design specifications as well as of joint development of products or components. Moreover, sharing of quality output data helps joint problem solving regarding product quality. Thus, information sharing is one of the most important steps towards developing a close relationship. Electronic data interchange is one of the recent technologies used by manufacturers and suppliers to enable rapid and efficient exchange of information.

Many manufacturers realize that suppliers know more about the products they supply. As a result, some involve suppliers early in new product design discussions to minimize subsequent number of modifications which can slow down product developments. Seeking the expertise of suppliers has gone a long way in helping some manufacturers to introduce new products faster and at a lower cost (Ansari & Modarress, 1988).

A manufacturer's capability to produce high quality products is highly influenced by its suppliers' abilities to supply high quality parts and components (Gentry, 1993). If the suppliers are unable to deliver the required quality, it can seriously affect the sales and reputation of the manufacturer. Therefore, if the manufacturer wishes to compete effectively and produce high quality products at a reasonable price, then it should help its suppliers improve product quality. Many manufacturers have initiated quality improvement programs for their suppliers in order to upgrade their quality standards as well as bring about improvement in other areas such as process control, packaging,

transportation and production costs. Companies such as Honda, Nissan and Xerox are constantly helping suppliers improve their product quality and other capabilities (Ansari & Modarress, 1988; Sheridan, 1990; Carr and Truesdale, 1992).

Quality of materials provided by suppliers invariably affect the quality of the manufacturer's output. One of the ways to improve the product quality and other capabilities of the supplier is through training the suppliers. Many leading companies are committing a great deal of their time and resources towards training suppliers to attain the most efficient manufacturing and management practices. Such companies include Xerox, Motorola and Honda (Hay, Jan. and May, 1990; Sheridan, 1990; and Magnet, 1994).

Thus information sharing, joint product development, supplier training and quality improvement programs are four important aspects of the M-S relationship we would like to investigate. This research examines the above four dimensions along with the five flexibility types (mix, changeover, modification, volume and delivery flexibility).

Purchasing and production managers of twenty-three firms in the electronics and telecommunications industries were personally interviewed. The data collected consist of both, qualitative and quantitative data. Results indicate a strong positive relationship between the three dimensions (information sharing, joint product development, and quality improvement programs) and the *mobility element* of the five flexibility types; mobility refers to how fast changes can be implemented. The effect seems especially strong in the case of information sharing and quality and continuous improvement programs based on both, the results of the regression analysis as well as opinions of managers.

Results also indicate a strong effect of supplier training on its quality, setup time, manufacturing process capability and delivery time. These improvements in supplier operations could enhance the changeover, modification and delivery flexibility of the manufacturer.

Most managers agree that information sharing is the "pillar" of a close relationship and stressed the importance of sharing production schedules and quality control data. EDI (Electronic Data Interchange) which is a new information technology was not found to be extensively used by most firms.

A large percentage of the manufacturers surveyed seem to seek the expertise of their suppliers and allow them to significantly participate in joint product development efforts. Contrary to expectations, the dimension of joint product development did not show a strong effect on changeover and modification flexibility.

Most manufacturers have instituted some kind of training programs for their suppliers. The benefits of both formal and informal training programs seem to be greater than informal training programs alone. However, more manufacturers provide their suppliers with informal training, rather than formal training, or a combination of both.

A sizeable percentage of the manufacturers offer considerable help to their suppliers in areas of quality, planning and product design. Managers indicated that the most popular method of helping suppliers improve their capabilities is through offering expertise as needed.

The manufacturers seem quite aware of their suppliers' contribution to the growth of their firms. More than half of the manufacturers have started some mechanism to

formally recognize their suppliers' contributions such as "Supplier of the Year", "Vendor of the Year" awards.

Most managers agree that a better relationship with suppliers has improved their operational capabilities and reduced costs. However, only a few managers believe that the need to develop a close relationship with suppliers depended on the kind of products they manufacture, the competitive environment, company policies and their manufacturing strategies.

However, on the whole, all results point to the fact that developing a closer relationship with suppliers improves the operational capabilities of the manufacturer, in this case the five flexibility types. Much of our results confirm our expectations and support the widespread view that greater participation of suppliers can provide additional benefits to the manufacturer in terms of increased flexibility, lower costs and timely deliveries.

This study provides a better understanding of the relationship that needs to be developed between manufacturers and suppliers, if manufacturers wish to increase their flexibility. The results also show ways for both manufacturers and their suppliers to cooperate and jointly plan their activities, so as to achieve greater flexibility. Managers can use the study to identify the important dimensions along which M-S relationship could be developed to best suit their company policies and manufacturing strategies.

Finally, this study can provide a platform for developing benchmarks in the area of manufacturer-supplier relationship. Managers can use these benchmarks to determine where they stand on the relationship scale.

However, caution must be exercised before the results are unduly generalized. The data come from two regions of Canada and from a relatively low number of firms. Nevertheless, the sample provides a fair representation of industry in Ontario and Quebec.

Future research could examine the relationship existing in other industries and even in other countries so as to determine how firms in other industries or countries develop their relationship with suppliers. Other dimensions besides information sharing, joint product development, supplier training and quality improvement programs could also be identified that contribute towards the development of a close relationship between manufacturers and suppliers. The model used in this study to measure M-S relationship and manufacturing flexibility could be enhanced to better capture all the aspects of this relationship.

CHAPTER 2

LITERATURE REVIEW

The literature in the field of manufacturing flexibility is limited. The interest in recent articles started to appear in research journals only from the mid 1980's. Most articles on flexibility have focussed on explaining the notion of flexibility (Slack, 1984; Brown et al., 1984; Kumar, 1987; Swamidass, 1988; Gerwin, 1989; Sethi & Sethi, 1990; Suarez et al., 1991; Hyun and Ahn 1992; and Upton, 1993). Only a few empirical studies have been reported (Piore & Sabel, 1984; Jaikumar, 1986; Tombak et al., 1988; Gerwin and Tarondeau, 1989; Dixon, 1992; Pal and Saleh 1993; and Upton, 1993).

In this chapter, the literature on flexibility will be reviewed. Types of flexibility, namely mix, changeover, modification, volume, rerouting, material and delivery flexibility will be defined and elaborated. The review will also discuss the possible effects of manufacturer-supplier relationship on the various flexibility types. To illuminate the context several other factors affecting flexibility will be reviewed along with the M-S relationship.

2.1. Concept of Manufacturing Flexibility

Researchers have presented two broad views of flexibility. Some see flexibility in terms of ability of machines to adapt to different requirements (Jaikumar, 1986; Fine & Pappu, 1988; Gerwin & Trondeau, 1989). Others define it in terms of the skills and

adaptability of people (Piore & Sabel, 1984; Pal and Saleh, 1993). Moreover, flexibility has also been analyzed at different levels, at the machine level and system level (Gerwin, 1993). Machine level flexibility represents flexibility achieved mainly through the use of equipment (machines & tools), and the various types of processes that they can accommodate efficiently. System level flexibility, on the other hand, is much broader and considers the general manufacturing system objectives of the firm (Brown et al., 1984; Sethi & Sethi, 1990). In other words, it defines the flexibility of the whole system and is at the function level.

One of the early writers on flexibility, Swamidass (1988), defines it as "the capacity of a manufacturing system to adapt successfully to changing environmental conditions and process requirements." To him, flexibility is "the ability of the production system to cope with the instability induced by the environment" (p.2). Environmental uncertainties include demand and process uncertainties.

According to Kim (1991), "manufacturing flexibility is not only about how quickly a manufacturer can adapt itself to changing conditions and environments, but also about how well it can lead in changing such conditions and environments" (p.4). This observation implies that manufacturers need not only be capable of successfully responding to changes brought about by others, but should also be able to introduce changes in the environment, forcing its competitors to adjust their operations in response. In other words, a manufacturer can use flexibility to stay ahead of its competitors by constantly redefining the conditions and environments in which all must compete (Gerwin, 1989; Kim, 1991).

Upton (1993) refines the concept by introducing time and cost. To him, flexibility is the ability to change or react with *little penalty in time, effort, cost or performance*. Upton's definition is robust although a distinction between the terms "change" and "react" would have improved it further. One of the impressive features of the definition is the importance of efficiency in making the required changes. It is necessary that the required changes be made as efficiently as possible with the least amount of sacrifice in terms of time, effort, cost or performance. The efficiency in making changes will indicate how flexible a firm is.

Borrowing from the notions discussed above, flexibility can be defined as: The ability of a manufacturing system to successfully adapt to demand and process uncertainties. The lesser the expense in terms of time, effort, cost, or performance for the system to bring about changes in mix, volume, design or delivery time of its products, the more flexible it is.

2.2. Taxonomy of Flexibility

There are various types of flexibility and many of these overlap. After examining 20 types, Swamidass concludes that "identical flexibility related terms used by more than one writer do not necessarily mean the same thing" (Kim, 1991; p.5). Some of the more well-known terms found in the literature include mix flexibility, volume flexibility, changeover flexibility, modification flexibility, process flexibility. The fact that different definitions are used for identical terms and that different names often refer to the same type of flexibility has caused unnecessary confusion (Suarez et al., 1991), and no doubt

slowed the progress in this area.

For example, Gerwin's (1982) definition of *mix flexibility* as 'the ability of a system to manufacture a mix of products simultaneously' is different from Slack's (1984) definition of *product mix flexibility* as 'the ability to manufacture a particular mix of products within a minimum planning period.'

Similarly, Gerwin's (1982) definition of *mix flexibility* is the same as that of *process flexibility* by Brown et al. (1986), and by Sethi and Sethi (1990). Appendix A lists the various types of flexibility used by some authors. Extensive reviews of the literature on manufacturing flexibility can be found in Sethi and Sethi (1990), Suarez et al. (1991), and Hyun and Ahn (1992).

This research will use Gerwin's (1989) classification of manufacturing flexibility. Gerwin, in 1989, defined flexibility at the machine level, but modified his view in a later work (1993) in which he discusses the multi-dimensionality of flexibility and its applicability to different hierarchial levels within an organization. His classification includes six dominant flexibility types: mix, changeover, modification, volume, material and rerouting flexibility. These flexibility types, with minor exceptions, are applicable at the individual machine, manufacturing system or cell, plant or multiplant levels. In other words it is applicable at different hierarchial levels.

This classification was suitable to our research objective as it can be applied to all levels, from the individual machine to multiplant levels. Similarly, these definitions can be applied to different types of industries and technologies. For example, Gerwin's definition of mix flexibility as the ability of a system to produce a variety of products at

any given period of time can be applied to any industry such as food processing, cars, electronics, computers, home appliances etc.

Moreover, these five types occur at the manufacturing system level (Gerwin 1993) and since M-S relationship is not at the machine level, and involves many groups at both ends such as manufacturing, purchasing and design, it is more likely to be affecting the system level flexibility rather than machine level flexibility. Machine level flexibility refers to the ability of the machines (tooling, adaptable fixtures, diagnostic software, multi-purpose, multi-axis adaptable computer numerical control machining centres etc.) to perform effectively without substantial effort in terms of time and cost to switch from one operation to the other (Sethi and Sethi, 1990; Gerwin 1993).

System level flexibility can be used to define the flexibility of the entire system and includes most of the machine level flexibility types Slack (1987). Suarez et al., (1991) are of the view that Gerwin's classification includes other kinds of flexibility, and can be better used to explain changes in the manufacturing system, both of a general nature and those related to specific manufacturing or operations problems. They also believe that Gerwin's flexibility types affect business performance more directly than other kinds of flexibility. As a result, they are more relevant for linking operational capabilities with the manufacturing strategy of the firm. One of the elements of a firm's manufacturing strategy includes its purchasing policy, which pertains to suppliers. Other reasons for adopting Gerwin's classification will be discussed in the following sections as each flexibility type is examined.

2.2.1. Mix Flexibility

Mix flexibility is the ability of a system to produce a variety of products/components at any given period of time. This flexibility allows a manufacturer to handle a range of products or variants by reducing setup time. This flexibility is important as it allows response to distinct customer tastes by producing a greater variety and satisfying more segments of the market (Suarez et al., 1991).

Mix flexibility is influenced by a number of factors but most importantly by process technology, production planning, control procedures, production layout and work organization (Slack, 1984). As we will see, suppliers can also have a major impact on mix flexibility, particularly in the case of a firm which subcontracts a large number of critical components used in many models of its product mix.

2.2.2. Changeover Flexibility

Changeover flexibility is the ability of a system to introduce or substitute new products over a given period of time. Changeover flexibility allows a manufacturer to quickly start producing a product without major retooling or significant new investments. With shorter product life cycles and changing customer tastes, the ability to rapidly introduce new products in the market often enables a firm to stay ahead and capture a greater share of the market (Suarez et al., 1991). Changeover flexibility allows a firm to quickly bring newly-designed products to the market (Carter, 1986; Gerwin and Tarondeau, 1989).

Changeover flexibility is influenced by process technology, labour skills, product design, and job design (Slack 1984; and Suarez et al., 1991). Suppliers can influence the changeover flexibility of the manufacturer by participating in the development of new parts or components, and promptly producing them for the manufacturer. This enables the manufacturer to quickly start producing the new product.

2.2.3. Modification Flexibility

Modification flexibility is the ability of a system to implement minor design changes in a product. When a new product is introduced, minor design changes may be required if the product attributes do not exactly match the customer's requirement, or if the customer makes some changes in the specifications (Gerwin, 1993).

Modification flexibility is chiefly dependant upon the capability of the production equipment to accommodate for minor retooling and programming, and also on the skills of the workforce to quickly adapt to new equipment and operating procedures.

Suppliers can influence the modification flexibility of the manufacturer by participating in its efforts to implement the minor design changes and making the required modifications in the parts or components that it supplies to the manufacturer.

2.2.4. Volume Flexibility

Volume flexibility is the ability of a system to efficiently adjust its production level within a large range to respond to unexpected fluctuations in demand. It permits increases or decreases in the aggregate production level. When the volume demanded by

customers is uncertain, the ability to quickly change production volume is an asset (Suarez et al., 1991). Furthermore, if a manufacturer has both mix and volume flexibility, the production of any product model can be easily increased or decreased depending on the level of demand.

Good relationships with suppliers and backward integration have been said to have a significant influence on the volume flexibility. If the suppliers can quickly respond to unscheduled changes in production levels, a higher volume flexibility can be achieved (Suarez et al., 1991). Volume flexibility is also dependant upon adjustable production equipment, high workforce flexibility and labour policy to vary the number of workers (Suarez et al., 1991).

2.2.5. Rerouting Flexibility

Rerouting flexibility refers to the ability of a system to reroute the production flow in case a breakdown occurs in one of the production stages (Suarez et al., 1991). In other words, it is the ability of a system to produce a part by alternate routes. These alternate routes may use different machines, different operations or different sequences of operations (Sethi and Sethi, 1990).

Rerouting flexibility allows for efficient scheduling of parts by achieving a better balance of machine loads. Moreover, it allows the system to continue production of a given set of parts, probably at a reduced rate, when unanticipated events such as machine breakdowns, late delivery of tools, delivery of incorrect or defective parts occur (Sethi and Sethi, 1990). As a result this type of flexibility is associated with the strategic need

to meet customer's due dates (Gerwin, 1993).

Multipurpose machines, machines with similar processing capability, system control software, versatility of material handling system and operation flexibility of parts affect rerouting flexibility (Sethi and Sethi, 1990). Suppliers also influence the rerouting flexibility in case of late delivery of parts and delivery of incorrect or defective parts.

According to Suarez et al., (1991) rerouting flexibility can be considered within the realms of volume and delivery time flexibility. When a system possesses the ability to handle a breakdown in the production process, it allows the firm to continue its manufacturing activities. As a result, it is able to maintain its aggregate production level and meet customer deadlines even if a machine breaks down.

2.2.6. Material Flexibility

Material flexibility is the ability of a manufacturing system to handle unexpected variations in inputs (Gerwin, 1993). It helps improve average product quality.

This definition is narrow from a system's viewpoint and cannot be considered at the same level as mix, volume, changeover, modification and delivery flexibility. Material flexibility is influenced by machines which can handle variations, system control software and multi-skilled workers.

According to Gerwin (1993), "A supplier's or a firm's upstream activities are sources of uncertainty for the compositions and dimensions of the materials being processed and due to these reasons, there is a need for material flexibility." (p.400). Although suppliers influence the material flexibility of a firm, it is at the machine level

and it is possible that at this level other factors and flexibilities subsume the influence of suppliers on material flexibility. This is one of the arguments in favour of omitting the study of material flexibility from this research. Views of various researchers are presented in the following paragraphs which would further help in arguing the case of the omission of material flexibility.

Since both, rerouting and material flexibility are to a great extent applicable at the machine level, this study did not consider the above two flexibility types. These two types of flexibility were replaced by **delivery flexibility** which presents a much broader view and is applicable at the systems level.

Many researchers have argued that mix, changeover, modification, volume and delivery flexibility are at the same level and when placed in a group, are sufficient to examine the operational capabilities and business performance of the firm. At the same time, material flexibility is not considered at this level and is said to overlap with delivery flexibility.

Kumar's (1987) definition of material flexibility is similar to that of Gerwin's (1993), that is, the ability of the system to accommodate for uncontrollable variations in the specifications of the inputs. Kumar further explains this flexibility as the capability of the machine (fixtures, power train, or tooling) which facilitates the adoption of non-conforming parts or raw materials. Moreover, he believes that material flexibility is related to machine flexibility and that the existing definition of machine flexibility should be broadened so as to include material flexibility. Thus, the view of Kumar would place material flexibility more at the machine level rather than at the system level. It is

necessary to note that, this study examined the effects of M-S relationship on flexibility at the system level and not at the machine level.

Slack (1987) has presented two elements of flexibility, resource flexibility and system flexibility. He defines resource flexibility as "the inherent flexibility of the manufacturing resources themselves, both structural (process and labour) and infrastructural (supplying and control systems)" (p.26). Material flexibility belongs to the first category, that is, resource flexibility. The second category, system flexibility, consists of the general manufacturing system objectives which define the flexibility of the whole system. In this category, he includes product flexibility, which corresponds to changeover and modification flexibility of Gerwin. The other flexibilities included are mix, volume and delivery flexibility. Thus, these five flexibility types are at the system level. Some researchers have characterized Slack's system flexibility as function-level flexibility describing them at the function level. Sethi & Sethi (1990), have included these five types in the definition of market flexibility, which is needed to meet rapidly changing markets. Market flexibility allows a firm to meet changes in environments such as rapid technological innovations, changes in customer tastes, short product life cycles and uncertainty in sources of supply. This is in agreement with views of Hutchinson and Holland (1982) and Fine and Li (1988). Sethi & Sethi further state that good relations with suppliers are very important in influencing the market flexibility of the firm.

Suarez et al., (1991) have selected four types of flexibility - mix, volume, new product (changeover and modification), and delivery time. They believe that these four types include other kinds of flexibilities, both of a general nature and those related to

specific manufacturing or operations problems. They support this view by giving a few examples. For example, routing flexibility can be considered within the domain of volume and delivery time flexibility. Similarly, material flexibility which represents the ability of the system to handle uncontrollable variations in the inputs will be reflected in the system's ability to handle volume fluctuations and speed up delivery. Moreover, they state that these four types of flexibilities apparently affect business performance more directly than other specific kinds of flexibilities. As a result, they are more relevant for linking operational capabilities with managerial strategy. One of the managerial strategies includes the decision whether to develop a close relationship with suppliers, which is the focus of our study. In addition, this study examines the effects of the various dimensions of a close relationship on business performance and operational capabilities of the firm. Thus, considering Suarez et al's views, the five types that have been selected (mix, changeover, modification, volume and delivery flexibility) suit the general objectives of this study.

Based on the above arguments, it was decided to exclude rerouting and material flexibility from this study.

2.2.7. Delivery Flexibility

Delivery flexibility is the ability of a system to effectively alter its scheduling at short notice, so as to deliver on short lead times and satisfy customer needs. With increased product variety and competition, the ability to deliver on-time and in small lots has become vital to effectively serve customers.

Suppliers have a critical impact on the delivery flexibility of the manufacturer. This is because the manufacturer's ability to deliver on short lead times is considerably influenced by the supplier's ability to promptly deliver parts/components in the required lots to the manufacturer. Delivery flexibility is dependent upon production-management techniques such as JIT, vertical integration and information systems (Suarez et al., 1991).

This study essentially considered five types of flexibility, namely: mix, changeover, modification, volume and delivery flexibility. These five flexibility types cover all the aspects of manufacturing that are relevant to the discussion of manufacturer-supplier relationships. Also, concepts are applicable systemwide and not merely at the machine level.

These five flexibility types, when investigated in case of a particular firm can give a fairly clear picture as to whether a firm is flexible or not. For example, the ability of a firm to respond to different customer tastes is reflected in its product variety or its **mix flexibility**. Similarly, its ability to efficiently adjust the production level in response to demand fluctuations is reflected in its **volume flexibility**. The firm's ability to compete, innovate and respond to customer demands will be affected by its ability to introduce new products and efficiently make modifications in its existing product line. These abilities are reflected in the **changeover** and **modification flexibility** of the firm. Lastly, the manufacturer should be able to deliver the required quantities of products to its customers on time. This ability is its **delivery flexibility**.

It is difficult to operationalize these flexibility concepts using Gerwin's terms alone. The development of any measure of flexibility must include two components: a

measure of diversity or range of possible actions of a system and a measure of time (Crowe, 1992) to change from one action mode to another. Once these two components are identified, the next step is to determine which of the two components of flexibility are required, and to what degree they are needed (Upton, 1994). With reference to this concept, many researchers have put forth their views on the different elements of flexibility which are discussed in the next section. A combination of these elements with Gerwin's classification will help us in developing measures for the five flexibility types.

2.3. Elements of Flexibility

Slack (1987) broke the notion of flexibility into three elements: the **time** and **cost** of making change, and the **range** of states a production system can attain. The cost here refers to the cost of moving from one production state to another, not the investment needed to provide that capability such as tooling and software requirements.

Slack insists that emphasis on either time or cost raises the likelihood that one element may be optimized at the expense of the other. For example, a firm may take excessive time to change from one product to another in order to minimize tooling costs. Dixon (1992) reports that in the case of the greige cloth manufacturing, a segment of the textile industry, time and cost are interrelated. He found that a longer time period for achieving a changeover is associated with higher cost which would be true in many cases. Also, cost as an element of flexibility is difficult to evaluate, since few companies maintain records of costs in a form directly applicable to flexibility measurement making it difficult for flexibility researchers to gather evidences for their arguments.

Kumar (1987) introduced an entropy measure for flexibility based on two elements of flexibility, the range of options available and the freedom of moving from one option to another. The freedom can be measured in terms of effort, cost or time required to change from one state to another. In this case flexibility depends not only on the availability of alternatives but also on the extent to which the diversity of choices is determined by the prevailing circumstances. This means that a firm does not enjoy the privilege of choosing from a host of alternatives, but its choice would be limited by the feasibility of moving from one option to another in terms of time, cost and other resources.

Upton (1994) redefined the elements that describe the efficiency of a change. He called these elements **range**, **mobility** and **uniformity**. The range element is the same as that explained by Slack and Kumar, namely the number of feasible options available within the range. The mobility element corresponds to Kumar's notion of freedom. Upton's mobility element captures the role of time and cost in an aggregate form unlike Slack. Uniformity refers to the extent a system operates equally well within one entire range. The three elements, range, mobility and uniformity are elaborated below.

2.3.1. Range

Range refers to the extent of variation that can be accommodated within a given flexibility dimension. Ability to accommodate greater variations would imply a greater number of feasible options. Some of Upton's examples explain this:

- the number of diverse components that can be processed,

- the range of volumes of output for which the plant is profitable,
- the variety of products that can be produced.

The main emphasis of this element is on the "*ability to change*"¹ component of Upton's definition. Range may be characterized by the number of feasible positions within the limitations of a given flexibility dimension, or some measurable distance between extremes of the range. A larger range implies greater flexibility as it signifies a larger option set. The five types of flexibility discussed previously can be related to this element in the following ways:

i) The range of mix flexibility can be measured by the variety of products that can be produced by the system. (Q10a)²

ii) The range of changeover flexibility is indicated by the number of major design changes that can be implemented on a given product (Gerwin, 1993). A major design change would involve greater number of processes and efforts in terms of time, cost and other resources. For example, a firm producing audio equipment would consider adding features such as a CD player, Dolby "B", "C" and "S" and 3 motors controlling each "head" to its existing twin cassette stereo as a major design change. (Q10c)

iii) The range of modification flexibility refers to the number of minor design changes that can be implemented on an existing product. Minor changes would involve less contribution in terms of time, materials and the number of processes involved. On the basis of the above example, minor design changes might involve the manufacturer adding

¹ as on p.5

² The number in parenthesis refers to item number in the questionnaire in Appendix B

small features to the new model (twin cassette stereo with CD player) such as an MPX filter, pitch control and continuous playback. (Q10e)

iv) The range of volume flexibility is the extent to which changes in the production rate can be made without substantial loss of profit (Gerwin, 1993). A lower break-even point would signify a greater ability to handle large fluctuations in the aggregate production level. (Q10g)

v) The range of delivery time flexibility refers to the extent of variations that can be made in schedules so as to meet customer due dates. (Q10i)

2.3.2. Mobility

Mobility is the ease with which a system moves from one point to another within a specified range along the dimension of change. For a flexible system the penalties for moving within a range are small. Mobility may be measured in terms of time, cost or both. Time refers to that which is needed for a change to take place. Cost refers to the cost of making the change or difficulty in making the changes. Kumar (1987) calls this the degree of freedom or the extent of ease in making the change.

i) The mobility aspect of mix flexibility can be measured by the average efficiency in terms of time and cost of switching production from one variety to another. (Q10b)

ii) Likewise, the mobility of changeover flexibility can be measured by the time and cost required to introduce a new product in the market. (Q10d)

iii) The mobility of modification flexibility refers to the time and cost required to implement a minor design change in an existing product (Gerwin, 1993). (Q10f)

iv) Mobility of volume flexibility refers to the time and cost required to react to variations in the aggregate production level. (Q10h)

v) The mobility aspect of delivery flexibility refers to the time and cost required to make the necessary adjustments in scheduling and processing in order to meet customer due dates. In other words, it refers to the ability to deliver on short lead times. (Q10j)

2.3.3. Uniformity

Uniformity is the third element of flexibility as classified by Upton. Uniformity measures flexibility in terms of the consistency in performance within a range - performance measured as yield or quality of output. According to Upton, in a more flexible system the performance would be more consistent throughout a range than in a less flexible system. The concept of uniformity exists only for a given within the range and is undefined outside the range.

Uniformity is more likely to be affected by the production system in comparison to range and mobility of flexibility, which could be influenced by many other factors. For example, the range of modification flexibility can be affected by worker skills, information system and availability of modified parts. The mobility of modification flexibility can be affected by the supplier's ability to provide the modified/new parts on time, financial policies and unions. Thus, range and mobility are more easily influenced by other factors and it is possible to measure the affect of such factors on the range and mobility elements of the different flexibility types.

This study used Upton's two elements, namely, **range** and **mobility**. The third element **uniformity** was excluded for a number of reasons. First, the focus of this study was on the impact of a better relationship with suppliers on the manufacturer's flexibility. A number of researchers acknowledge that there are many factors affecting the flexibility of a manufacturing system besides manufacturing technologies.

All factors affecting flexibility do not affect the uniformity property, which is primarily a function of the production system (tools, equipments and machinery). That is, the uniformity in performance is a function of the ability of machines to produce a consistent quality or rate of output. Organization structure, layout etc. may have strong effect on number of options available but cannot be conceived to have significant influence on the yield within a range. Thus, uniformity in flexibility can be considered very much internal to the production system and it would be difficult to establish if there are any other factors besides worker skills which can influence the level of uniformity. As a result, it would be difficult to establish a link between relationship with suppliers and uniformity as an element of flexibility.

Following this argument, inconsistency within a specific range could be generally traced to some flaw in the mechanical system. Inconsistency could also be material related but in such cases the entire batch produced would not conform to the specifications. Thus, within a range, performance would still be consistent, that is, an entire batch having the same defect. Therefore, analyzing the production system would be one of the best methods of evaluating uniformity. Uniformity could be improved by adjusting the machines, layout or adding new tools and equipments.

Thus, considering the scope and focus of this study as well as the arguments provided in the preceding paragraphs, this research focusses on Upton's two elements only, range and mobility, together with the five flexibility types such that the concept of flexibility can be better measured and understood. The above framework is feasible to study the effect of the different flexibility types with respect to their range and mobility on different factors, especially on M-S relationships. This framework will also help in defining and measuring the different flexibility types more explicitly.

2.4. Factors Affecting Manufacturing Flexibility

Flexibility is a multi-dimensional concept, and is influenced by a number of factors besides automated manufacturing technologies (Piore & Sabel, 1984; Suarez et al., 1991). Although it is not possible to examine each factor in detail, we will briefly review some of them, but concentrate primarily on the main subject of the study, namely M-S relationship and its impact on the different flexibility types.

Once some of the factors are examined, the multi-dimensional aspect of flexibility will be better understood. Some of the factors said to have effects on flexibility are:

1. Backward Integration
2. Supplier Relationship
3. Multi-skilled Workforce
4. Preventive Maintenance
5. Quality Control
6. Rules & Procedures

7. Layout and plant configuration

8. Information System

9. Machines and Equipment

Some of the factors are elaborated below:

1. **Backward Integration:** Backward integration is one of the strategies through which a manufacturing firm can become more flexible by controlling the supply of the materials and components that it uses. Such strategies reduce overall production costs, as well as assure the firm of a stable supply of important parts and components.

Backward integration helps to internalize more phases of the business starting with conception, design, manufacture to customer distribution. As a result, a firm is able to modify an existing product or develop a new one according to the demand and market conditions (Macbeth & Ferguson, 1991). Minor changes in a product are also possible, due to greater control over supplies and through better utilization of financial and technical resources. These advantages help to increase the **changeover** and **modification flexibility** of the manufacturer.

In addition, it provides the ability to deliver on short lead times, thereby increasing the **delivery flexibility** of the firm. For example, locating manufacturing plants in foreign countries allows the firm to respond to varying customer tastes in different national markets within a short period of time.

2. Multi-skilled Work Force: Humans are still the most flexible subsystems in a manufacturing system. The notion that the new flexible technologies are infinitely flexible and hence capable of doing almost anything is not true. The human worker is still more flexible and possesses a superior ability to learn and adapt to new circumstances, to perform tasks requiring a high degree of coordinated motion, or to process complex information than any machine (Pal & Saleh, 1993). Thus, flexible technologies are flexible only within a predefined range of possibilities, which may be somewhat higher than that of traditional hard automation but which is still very narrow (Duimering, Safayeni and Purdy, 1993).

Firms having highly trained, multi-skilled workers achieve higher flexibility than firms pursuing division of labour and specialized skills. A multi-skilled worker can perform a variety of jobs, and is thus able to perform multiple jobs and handle flexible job assignments. In other words, the number and type of jobs performed by an operator at a time can be increased or decreased as needed, which can offer considerable adaptability to product mix variations (Gerwin & Kolodny, 1992; Pal & Saleh, 1993). Thus, the skill and ability of operators can influence the **mix flexibility** of the firm. Sorge and Warner (1980) observe that the broader training provided to workers in German plants increased their flexibility. Similarly, a comparative study of FMS (Flexible Manufacturing Systems) in the US and Japan by Jaikumar (1986) showed that the high degree of technical literacy of the Japanese workers in the flexible manufacturing systems, makes such systems more flexible than their U.S. counterparts.

Skilled operators adapt quickly to new equipment and operating procedures, thus making it easier to add or substitute new products as well as implement minor modifications in existing products. Thus, worker skills can increase the **changeover** and **modification flexibility** of the firm. At the same time, labour policies regarding work shifts, layoffs, hiring and overtime can influence the **volume flexibility** of the firm. According to Suarez et al.,(1991), volume flexibility is also dependant upon adjustable production equipment, high workforce flexibility and labour policy to vary the number of workers.

Workforce, therefore, plays a very important role in increasing, as well as maintaining, the flexibility of a firm.

3. Preventive Maintenance: Preventive maintenance plays an important role in supporting the smooth functioning and improving the flexibility of a manufacturing system. Since automated systems are extremely expensive and complex, maintenance assumes a critical role.

Each component within the FMS represents new development in manufacturing technology and appropriate knowledge is required for debugging and maintenance (Lenz, 1989). Debugging and maintenance are necessary to prevent breakdowns and disruptions in production, which could adversely affect the flexibility of the firm.

4. Rules and Procedures: Kim (1991) has defined rules and procedures as formal and informal practices adopted by an organization to carry out its diverse activities such as

planning and scheduling, product and process designing, engineering, manufacturing, marketing, servicing customers, recruiting and training.

After studying 40 FMS installations in several countries, Dempsey (1983) reported that "on average, 40% of the benefits predicted for an FMS are in fact achievable or have been achieved before the FMS is delivered and often within six months. This is because the planning process itself has highlighted existing custom and practise which . . . can be put right without major investment" (Slack, 1987, p.25). Similarly, Bessant and Haywood (1985), after studying FMS in the UK, reported that "approximately half of the benefits of FMS were derived from managerial and work based organizational changes" (Slack, 1987, p.25).

Thus, simplifying rules and procedures as well as eliminating unnecessary organizational hierarchies are bound to have a significant influence on the operational flexibility of a firm. Since rules and procedures cover diverse activities and are related to the general efficiency of the firm, it is difficult to point out precisely the different flexibility types that they influence.

5. Information System: The speed at which information can be retrieved and processed is becoming increasingly important. This is because systems decisions are being increasingly linked to other operational functions. This requires an appropriate information/control system that can remove bottlenecks, eliminate the unpredictability of a manufacturing process, improve product and part availability, and also enhance customer service (Hass, 1987).

According to Kim (1991), engineering, manufacturing, marketing and sourcing databases all play important roles in increasing flexibility: computer-aided product design databases help reduce product design cycle times; computerised marketing databases speed processing customer order entries and shipping finished products; and computerised WIP (work-in-process) tracking databases help reduce manufacturing cycle times. These reductions in product design cycle times and manufacturing cycle times enable a firm to design and modify products, as well as introduce them much faster into the assembly line. This increases the **changeover** and **modification flexibility** of the system. In addition, a reduction in the manufacturing cycle time as well as the ability of the marketing databases to quickly process incoming orders and shipping finished products both help a firm achieve greater **delivery flexibility**.

Information systems can be a vital link that effectively unites the different components in manufacturing, allowing the firm to react faster to customer demands and process related problems, thereby increasing the flexibility of the firm.

6. Machines and Equipment : Programmable machines are more flexible than machines which cannot be programmed. Since machines and equipment represent process technologies of the system, they influence a number of different flexibilities. According to Slack (1984) and Suarez et al.,(1991) process technology is an important determinant of mix, changeover, modification and volume flexibility. The machinery could be built or programmed to handle a number of different parts (**Mix flexibility**). Similarly, the machinery could be built in such a manner that it easily allows the addition of new

products as well as their modification without extensive retooling (**Changeover and modification flexibility**). Multi-purpose numerically controlled machine tools shorten set-up time and also easily allow minor design changes. Such changes are even more easily handled by CNC (computer numeric control), DNC (Direct numeric control) and FMS (Carlsson, 1989). Also, machines could be built and programmed to handle different levels of capacities efficiently (**Volume flexibility**). Numerically Controlled tools possess the ability to operate plants at varying rates. Different types of machines influence the various types of flexibility to different degrees.

From the above considerations of factors we can infer that reductions in manufacturing cycle times and set-up times are due to the combination of reliable flexible machines, multi-skilled workers, close coordination between several departments, good relationship with suppliers, effective information systems, preventive maintenance, simple layout and several other factors.

Similarly, the above discussion implies that there are various approaches to achieving flexibility and the best way of attaining the optimum flexibility would be to use a suitable combination of the above approaches, depending on the manufacturing strategy adopted by the firm.

2.5. Manufacturer-Supplier Relationship

In the early 1960's, the primary functions of purchasing were generally clerical, and were limited to sourcing, pricing and delivery. However, from the mid-1970's shortages of certain raw materials, the oil embargo, higher inventory carrying costs due

to high interest rates, inflation, longer lead times and new management techniques forced many manufacturers to rethink their purchasing strategy (Ansari and Modarress, 1988). Many companies therefore started focussing on reducing purchasing costs and treating the purchasing function more as a 'profit centre' (Ammer, 1969).

Hay (Jan, 1990) remarks that purchasing has now assumed a critical role in business and is as important to the success of the firm as areas such as finance, marketing, engineering, production control, and quality control. In most manufacturing companies, procuring raw material/components accounts for 60-70% of total costs. In fact, Hahn et al. (1990) believe that a firm's ability to produce a reasonably-priced quality product in a short time is significantly influenced by its suppliers' capabilities.

This importance of purchasing has motivated manufacturers to develop a closer relationship with dependable and competent suppliers. McMillan (1990) reports that, "about a quarter of the cost advantage of Japanese firms is due to the superior efficiency of their supplier networks". Many industry observers and researchers have described the emerging close relationships as "partnerships" and "strategic alliances" (Gentry, 1993).

However, none of the researchers have clearly defined the meaning of a close relationship. In this study a '*Close Relationship*' has been defined as a mutual, ongoing relationship between a manufacturer and its suppliers, involving commitments from both sides over a prolonged period of time. Such a relationship would be characterized by good communication, coordination and cooperation between manufacturers and their suppliers. The principal dimensions of such a close relationship are greater information sharing, joint product development, joint training programs, and quality and continuous improvement

programs. As a part of this relationship, manufacturers and suppliers would also share the risks and rewards (Ellram, 1991, Gentry, 1993).

In the following section, different arguments have been presented regarding size of supplier base and, advantages and disadvantages of a small supplier base. Section 2.5.2 discusses the benefits of a close M-S relationship. Some of the effects of suppliers on the flexibility of the manufacturer have also been discussed in this section. Section 2.5.3. examines ways of developing a successful M-S relationship through an example of a specific company.

Section 2.5.4 discusses the four dimensions of a close M-S relationship, namely, information sharing, joint product development, joint training programs, and quality and continuous improvement programs, and their impact on the five flexibility types (mix, changeover, modification, volume and delivery flexibility).

2.5.1. Supplier Base and Manufacturing Flexibility

Some firms choose their suppliers on the basis of cost. In order to better their cost position, some frequently change their suppliers providing them a large supplier base, and a greater flexibility³ in purchasing. However, this may lead to variations in the quality of materials. Furthermore, Kim (1991) argues that suppliers who offer the lowest prices may not provide the best quality.

Hay (1989) further notes, that some companies who have reduced their supplier base may not have chosen the best suppliers. Apparently, some fail to look outside their

³ Does not refer to manufacturing flexibility

current universe of suppliers and adhere to one or two of their current suppliers. He believes that this disadvantage could be reduced by ensuring that the selection team thoroughly evaluates potential suppliers in terms of requirements, product quality, price, delivery and other criteria, and then chooses the appropriate suppliers. It is also necessary that the selection team be comprised of not only purchasing personnel, but also of representatives from engineering, quality assurance, manufacturing, finance, and other departments.

Hall (1983) and Schonberger (1982), while supporting the above argument insist that establishing close relations with suppliers is critical to obtain better quality parts and components, to help introduce new products quickly and increase the manufacturing flexibility of the firm. They advocate the JIT⁴ (just-in-time) approach, which includes a small supplier base, information sharing, joint technological development of new products and timely supplier deliveries in small lots.

A small supplier base offers various advantages. Companies that wish to develop a close relationship with their suppliers need to limit the number of suppliers they deal with. The main reason is that close relationships require a considerable amount of interaction between the manufacturers and suppliers, and this limits the number of suppliers that can be dealt with effectively. The Xerox Company has reduced its pool of suppliers from over 5000 to 400, trained the key suppliers, and has also started involving them in the design of new products (McMillan, 1990). The use of a limited number of

⁴ "JIT is the logistical coordination between the buyer and seller to reduce inventory. The objective is to draw material through the production and distribution system on an 'as needed' basis rather than on a forced feed flow driven by an order quantity" (Dion et al., 1992 p.32).

suppliers offers various advantages to both parties involved. These advantages include:

1. Large volumes of business given to one or few suppliers provides them an incentive to deliver better service. It also induces the supplier to make investments in product improvement without fearing the loss of business to a competitor who may offer similar products or service at lower prices (Gupta et al., 1991).
2. In case of a small supplier base, manufacturers often receive most of their requirements from a single or couple of suppliers. Sheridan (1988) argues that buying a part from a single source minimizes the variability from part to part. This consistency from part to part reduces the manufacturer's need to achieve a higher material flexibility.
3. The volume of items purchased through each supplier is higher, which eventually leads to lower costs. Ansari and Modarress (1988) argue that when manufacturers represent large accounts for the suppliers, they are more inclined to pay attention to the manufacturers' requirements.

On the other hand, having few suppliers also has its disadvantages. For example:

1. Trevelen (1987) argues that if there is a strike or a production disruption, for whatever reason, at either the manufacturer or the supplier's plant the other party is adversely affected, due to the high interdependency. Such events may not assure a consistent supply of required materials, causing a disruption in production and delivery schedules, eventually affecting the delivery capability, in other words the delivery flexibility of the manufacturer.
2. Trevelen (1987) also adds that a manufacturer may have little bargaining power due to the limited supplier base. In case of emergency or shortages of materials, the supplier

could sometimes try to take advantage of the manufacturer.

3. Technical knowledge and manufacturing expertise are spread throughout the supplier industry. Partnership with a few suppliers may make it difficult for the manufacturer to acquire these benefits leading to cost and quality improvements (McMillan, 1990). Multiple sourcing allows the manufacturer to create competition among suppliers. If the manufacturer rewards each supplier on the basis of performance, it induces the suppliers to do their best to reduce costs, innovate and improve quality. Each supplier may possess special capabilities and multiple sourcing can allow the manufacturer to acquire the benefits of the expertise possessed by various suppliers.

4. According to Kim (1991), firms competing only on the basis of cost may require a large supplier base in order to pursue their strategy of competitive buying. In order to maintain low cost, they require the flexibility⁵ to choose from a number of suppliers.

It is clear that there are both positive and negative aspects to having a limited supplier base for both parties involved. Nevertheless, the current thinking is that the positives outweigh the negatives for manufacturers and suppliers alike. However, Newman (1989) considers that the usefulness and the applicability of both options depends on the specific buying situation and the strategy adopted by the respective firms.

It is interesting to note that the North American manufacturers enjoy a higher flexibility⁵ in purchasing than their Japanese counterparts. Stalk and Hout (1990), note that the Japanese have selected one or two suppliers and developed a close relationship with these few suppliers. The North American manufacturers, on the other hand, have

⁵ Does not refer to manufacturing flexibility

traditionally shied away from such a close relationship with their suppliers. The American managers presume that a large number of suppliers are needed to lessen the risk of interruption in supply as well as to keep prices competitive (Gupta et al, 1991). Managers of U.S. firms argue that the United States, being large in terms of economy as well as physical size, it is difficult for firms operating in the U.S. to maintain close relations with distant suppliers.

Furthermore, Newman (1989) argues that in case of a single supplier supplying to a large number of firms, it may be difficult for manufacturers to share vital information with that supplier. Also, if a supplier has very few customers, the loss of even a single customer could deliver a devastating financial blow to the supplier. This is because a contract with each manufacturer represents a large account for the suppliers and they may be devoting a major part of their production capacity towards manufacturing for each of their buyers. Such a situation may be applicable to any country and not specifically to the United States.

Stalk and Hout (1990) add that the Japanese manufacturers have used a small supplier base as a prerequisite to implement the philosophy of JIT. They have struck a strategic partnership with their suppliers to reduce the time needed to introduce new products and respond faster to customer needs.

The use of JIT also presupposes volume and time⁶ flexibility in ordering, as the supplier is required to deliver frequently in smaller quantities (weekly, daily or in some cases, up to three or four times a day). Small lot-sizes and frequent deliveries contribute

⁶ The ability to deliver on short lead times.

to higher productivity and flexibility through a lower level of inventory and scrap, better quality, lower inspection costs for incoming parts, and an earlier detection of defects (Ansari and Modarress, 1988). Frequent deliveries and small batches can also bring about mix flexibility. That is, it allows the manufacturer to produce small lots of a variety of products. This would however depend on the firm achieving set-up time reduction, and an efficient layout that promotes the smooth flow of products and components. Moreover, a reduction in supplier delivery times and the ability to deliver in small lots helps in increasing the delivery flexibility of the firm (Cuarez et al., 1991). This is because the ability of a manufacturer to make changes in its production schedule in order to deliver quickly and in required quantities, depends largely on the supplier's capability to deliver parts on time and in right quantities.

However, recently, supplier relations in the United States and Canada have also been undergoing vast changes. Helper (1991) notes that short term contracts and price based competition have been replaced by long term contracts, sole-sourcing in many cases, and competition is increasingly based on quality, delivery, and engineering as well as price. Chrysler, for example has followed the Japanese model. Kamath and Liker (1994), report that for Chrysler's new cars consisting of the LH line, a greatly reduced number of suppliers were utilized. Some of the key suppliers were involved in the early phases of the development cycle. Supplier bidding was virtually eliminated and suppliers were chosen even before the parts were designed. Some of these suppliers were even given the added responsibility of coordinating the development activities of the other

"lower tier"⁷ suppliers. Chrysler used 230 suppliers for the LH line in comparison to the New Yorker model which had 456 suppliers. By using a small supply base for the LH line, Chrysler reduced development time by over 25% and produced world-class vehicles incorporating state-of-the-art components at considerably lower cost than its competitors.

Thus, a small supplier base offers various advantages. It contributes towards implementing JIT and simplifies the process of developing a close relationship between manufacturers and suppliers.

2.5.2. Benefits of a Close M-S Relationship

A close relationship between manufacturers and suppliers has the potential of offering several benefits to both parties involved. It helps to reduce costs and share business risks (Gentry, 1993), improving quality by shifting the focus from price to the more significant issues of quality and technological improvement. Other important benefits include:

1. In a close relationship, management and production techniques can be shared across boundaries and both parties can get the benefit of each other's technological expertise, thereby helping to design and manufacture much faster, better quality parts and components. Magnet (1994) considers such a competitive edge to be critical in today's environment of rapidly changing tastes and short product life cycles.
2. A close relationship encourages suppliers to make long-term plans and investments.

⁷ Refers to the pyramid structure in which "lower tier" suppliers form the lower base of the pyramid above the "first tier" suppliers.

Suppliers can confidently invest in developing ideas and plans for the next line of products well in advance. This facilitates the manufacturer's effort to rapidly develop designs for the new products, thereby enhancing its **changeover flexibility**. Moreover, when a model change occurs, suppliers can make new changes faster since they continue to move down the experience curve (Dyer & Ouchi, 1993).

3. According to Gupta et al., (1991), a strong partnership allows suppliers and manufacturers to cooperate in problem solving and in handling uncertainties. The use of electronic data interchange (EDI) systems has been known to strengthen the relationship by allowing both parties to know other's production schedules and inventory data bases and, in doing so, reduce lead times and improve flexibility.

4. In a close relationship, manufacturers often involve suppliers in the early stages of product design. Early input of the suppliers' expertise and technical knowledge ensures that the parts can be produced without drastic changes in tooling, thus reducing costs.

5. Close relationship with a few suppliers may allow a firm to confidently subcontract a part of its requirements and achieve '**volume flexibility**' in this process (Suarez et al., 1991). During business upswings, manufacturers can fulfil the increased level of demand by purchasing a relatively higher portion of parts from their suppliers (Asanuma and Kikutani, 1992). As a result, a manufacturer can cope with a short term increase in demand by transferring extra production responsibilities to its suppliers and achieve a higher volume flexibility in this process. Mutual trust and commitment between manufacturers and suppliers ensures that vital product and process secrets are not revealed to competitors. Thus, the manufacturer can confidently subcontract technologically

sophisticated products or products in which it has a competitive advantage. Moreover, a long-term relationship compels the supplier to also share the responsibility to fulfil its client's (manufacturer) requirement (Trevelen, 1987).

6. Similarly, "suppliers can have a major impact on **mix flexibility** when a firm subcontracts a large number of critical components or assembly operations" (Suarez et al., 1991, p.30). A close relationship allows manufacturers to share information regarding product design and processes with their suppliers. This facilitates the subcontracting of critical components and even the assembly of major sections. And since the suppliers are involved early in product design and given considerable freedom in designing parts and components, they are able to design and produce some of the components themselves (McMillan, 1990). This allows suppliers to produce a greater variety of parts and components, as well as perform certain assembly operations. As a result, the supplier is able to simultaneously provide a greater variety of parts and subassemblies to its manufacturer, thereby enabling the manufacturer to produce or assemble a greater variety of products within a given time period.

7. Establishing close relations with suppliers is becoming important for another reason. In recent times, suppliers are playing an increasingly important role in developing new generation of products, especially in the computer and electronics industry. For example, computer makers and chip manufacturers have jointly collaborated in order to quickly develop new chips, thereby significantly reducing the design and manufacturing cycle time of new computers (Sheridan, 1988; Kim, 1991). Moreover, according to Carter et al.(1988), the electronics industry purchases more than 70% of its components from

external sources. Since this trend, as well as the miniaturisation of subsystems, is expected to continue in the future, Kim (1991) believes that the need for maintaining close relations with suppliers will become essential for most electronic and computer firms in order to introduce new products sooner and at competitive prices.

The role of suppliers, then, is undergoing dramatic changes, from being merely a source of cost-efficient inputs to a strategic partner providing important technical expertise high quality parts on a timely basis and even participating in the development of new products. Hahn et al. (1990), believe that a network of competent suppliers can significantly improve a manufacturer's ability to compete effectively.

However, the benefits alone do not show the ways to develop a close relationship. There are many other approaches and the following section shows the ways of developing a successful relationship through an example of a specific company.

2.5.3. Developing A Closer Relationship

Traditionally, North American manufacturers have used large purchasing departments to handle numerous suppliers on an arm's length and adversarial basis, playing off one supplier against another (Carr and Truesdale, 1992). The strategy was to purchase as cheaply as possible. The suppliers, on the other hand, would try to sell as dearly as possible, profit maximization being their only motive (Hahn et al., 1986). However, with increasing competition, manufacturing firms have realized the significance of developing close relationships with reliable suppliers and the managerial, technological and financial benefits they provide (Ellram, 1991).

A close relationship demands an absolute commitment by the top management of both the manufacturer and the supplier. The Honda Motor Co. provides an excellent example of how to develop a close relationship with the supplier. When Honda chose Donnelly Corp. in 1986 to manufacture all its mirrors for its U.S. manufactured cars, it was aware that Donnelly had never made exterior mirrors and even had no factory to make them. But Honda managers recognized that Donnelly's values matched perfectly with theirs. They liked the way Donnelly involved its workforce and positively utilized their intelligence, imagination and manual skills.

Honda developed a mini-reengineering program to strengthen its supplier. It sent engineers to Donnelly's plants and reorganized an entire section. The notable distinction between this relationship and others is that Donnelly built an entirely new plant in order to manufacture Honda's exterior mirrors, which required immense trust on the part of Donnelly. The result was amazing. From \$5 million in sales the first year (1988), the partnership is expected to grow to \$60 million by 1997.

Thus, we can see that a close relationship is a commitment between two corporations and not merely between a salesman and a purchasing manager. As a Honda manager pointed out to an executive of Donnelly, "To Honda, long term means forever, assuming you're doing the job" (Magnet, 1994, p.63).

2.5.4. Dimensions of a Close Relationship

A close relationship has a number of dimensions. One of the foremost steps though which a manufacturer and supplier can develop a close relationship is by *sharing*

information. It is necessary to communicate to perform any kind of joint activity or coordination, be it joint problem solving, production and delivery scheduling, training or even just knowing more about each other. Similarly, suppliers can give valuable insight when they are involved early in *new product design* by the manufacturers, and can positively participate in new product development. "Two heads are better than one", and manufacturers can always use the experience and suggestions of the suppliers. In order to use this relationship to its fullest potential, manufacturers should concentrate on improving *quality and other aspects* of the supplier, and one of the ways of achieving this objective is through *supplier training* programs. The next four sections discuss these four dimensions of a close relationship, that is information sharing, joint product development, supplier training and, quality and continuous improvement programs, as well as their effects on the five flexibility types; mix, changeover, modification, volume and delivery flexibility.

2.5.4.1. Information Sharing

Increased communication is one of the first steps towards developing a close relationship between manufacturers and suppliers. Exchanging and sharing information facilitates a number of cooperative activities such as joint problem solving, joint product development, joint investigation of product quality and delivery performance (Treleven, 1987). In other words, information sharing is the "pillar" of a close relationship, and therefore the importance of information sharing is also referred to in other dimensions.

There are various areas in which manufacturers and suppliers can share information. These include information regarding production schedules, minor design changes, new designs of parts or components, quality control data as well as cost data. Such information is exchanged via a variety of media such as postal mail, fax, telephone, E-mail, courier and Electronic Data Interchange. Nevertheless, one of the most efficient ways to communicate remains to be face-to-face communication. Japanese auto manufacturers place a high value on face-to-face communication with their suppliers. Although Toyota's suppliers are located nearby, they insist that suppliers send their engineers to Toyota's technical centre in Toyota City. When suppliers' and manufacturers' engineers sit in the same facility, it becomes easy to coordinate activities. Direct interaction is the best way to communicate complex, dynamic information during the development of new vehicle models (Dyer, 1994). Dyer (1994) also observed that better communication led to greater efficiency, faster product development cycles, and more reliable products.

One of the areas in which communication is vital, is production schedules. When manufacturers provide suppliers with accurate data regarding production schedules and requirements, it helps the supplier know the exact specifications in order to meet the deadline delivery schedule. Sheridan (1988) states that if there is regular exchange of production schedules between manufacturers and suppliers, any changes are promptly conveyed to the supplier, who can then make the necessary arrangements to reserve a certain proportion of the production capacity that would be necessary and sufficient to meet the customers demands. Such exchange allows the supplier to adjust its production

plan more according to the production schedule of the manufacturer. Similarly, the knowledge of a supplier's schedule can allow the manufacturer to make adjustments in its own production schedule. Such an arrangement helps reduce the lead time of the manufacturer and could improve its **delivery flexibility**. The flexibility element involved in this case would be *mobility*.

Information sharing, when institutionalised, allows a manufacturer to request a change in material supply to meet an unexpected fluctuation in demand. A greater commitment and cooperation between manufacturers and suppliers as well as the probable existence of a long term contract induces the supplier to take all possible measures to meet this demand. The ability of the supplier to meet a new level of demand at short notice can increase the **volume flexibility** of the manufacturer. The flexibility element involved in this case would be *mobility*.

When a manufacturer decides to make minor modifications in a product, it often requires simultaneous changes in the parts or components used in the product. If information concerning these changes are promptly provided to the suppliers, they can make minor changes in tooling or software in a timely fashion. This enables the manufacturer to make faster modifications in its product line which could enhance its *mobility* element of **modification flexibility**.

Similarly, when a manufacturer wishes to introduce a new product line, new parts and components may be required. If the suppliers promptly receive these new designs they can make adequate changes in tooling and procure the required raw materials. Also, when manufacturers and suppliers share greater amount of technical information it leads

to better understanding of each other's production processes. Kamath and Liker (1994) report that Toyota provides its key suppliers with a layout of the area surrounding the supplier's component system. This helps the suppliers' engineers better understand how their parts fit with other surrounding parts, and they even make suggestions as to how Toyota could change the design of mating parts to improve its own components.

When suppliers provide their customers with detailed breakdown of the steps in their production process it helps the customers ensure that their components designs are more compatible with suppliers' processes leading to improved productivity and quality (Helper & Sako, 1995). Thus, quick communication of new design information and better exchange of technical information can reduce the manufacturer's time to introduce new products, thereby improving its **changeover flexibility**. The flexibility element involved in this case would be *mobility*.

Hay (May, 1990) notes that information sharing between manufacturers and suppliers is becoming a wide spread practice. Companies such as Toyota, Motorola, Honda, Nissan, Chrysler and Xerox extensively communicate with their suppliers. The Xerox company once had a policy forbidding its engineers to speak with its suppliers, fearing leakage of sensitive information. However, having established a closer relationship with their suppliers, Xerox now insists that engineers talk to suppliers and keep an open line of communication. The manufacturers seem to be realizing that a close relationship can render such significant benefits in quality and costs that they could develop an advantage that its competitors would find difficult and time-consuming to duplicate.

Evolution of EDI Partnerships between Suppliers and Manufacturers:

One of the ways in which information is being increasingly shared between suppliers and manufacturers is through EDI (Electronic Data Interchange). "EDI is the direct computer-to-computer exchange of standard business documents such as invoices, bills of lading, or purchase orders between two separate companies" (Craighead, 1989). It also facilitates exchange of manufacturing information such as the purchasing company's schedule of purchased material requirements or the suppliers advance shipping notice. Taylor had predicted in 1989 that by 1995 EDI would become the primary mechanism for all intercorporate business transactions. Craighead (1989) notes that EDI can result in substantial savings of paper, time, and costs.

The automotive industry is one of the best examples of successful implementation of EDI. The Big Three (GM, Ford & Chrysler) have forced their suppliers to use EDI. The success has prompted them to expand EDI beyond component suppliers to the vendors of indirect materials such as office supplies.

Electronic data interchange offers various advantages over conventional forms of business communication. These include:

1. It facilitates the sharing of production information and helps coordinate the supplier's production with the manufacturer's requirements (Craighead, 1989).
2. It allows for transmission of complete technical specifications as well as designs by CAD system of a manufacturer (Biby, 1992; De Toni et al., 1994). This gives suppliers an opportunity to evaluate the information as well as quickly receive new designs or changes made in existing designs. At the same time recommendations or feedback can be

sent by the supplier to the manufacturer. This way EDI allows the manufacturer to quickly incorporate the feedback into new designs. As a result, product development time and costs are substantially reduced and modifications to existing products can be quickly brought about. This could help in increasing the **changeover** and **modification flexibility** of the manufacturer. The flexibility element involved in both types would be *mobility*.

For example, Federal-Mogul Corp., a manufacturer of automotive seals, has been able to significantly reduce its lead time by directly sending CAD drawings to the car makers' computers (Ford, GM and Chrysler). As a result, drawings do not have to be shuttled back and forth between Federal-Mogul and the auto makers, thus allowing designs and products to be modified and developed much faster (Boudette, 1989).

3. Any urgent requirements for additional parts or components can be quickly transmitted to the supplier, who can then make the necessary arrangements to meet this new requirement. This could help in increasing the **volume flexibility** of the manufacturer, affecting the *mobility* element of this flexibility.

4. EDI helps in reducing errors and results in substantial savings in costs in terms of processing incoming mail and checking documents for accuracy (Milbrandt, 1990). Moreover, EDI can automatically issue a purchase order, based on present inventory thresholds. As a result, errors originating due to the manual method of ordering is eliminated resulting in faster and more accurate exchange of purchase requirements (Biby, 1992).

5. Bailey (1990) remarks that EDI simplifies the process of transportation by allowing shipping schedules to be furnished without the customary documents. Prompt exchange

of delivery information and an expedient transportation documentation helps reduce the delivery time of the supplier. This can help in reducing the lead time of the manufacturer.

It is evident that EDI offers many advantages to both suppliers and manufacturers. Using the EDI network a manufacturer can establish a smooth flow of information to its suppliers and possibly enhance its flexibility. However, Banerjee and Goldhar (1993), argue that EDI is a fairly new technology and no set standard for data transmission has yet been developed. This hampers the transmission of data between partners, making it difficult to fully utilize the potential of EDI. Nevertheless, the uniqueness of EDI and its ability to rapidly exchange information is bound to have a significant influence on the development of M-S relations.

In sum, information sharing is a vital step towards developing a close relationship. An improved two-way communication allows suppliers to know more about the products and processes of the manufacturer, and also helps them to develop a better understanding of the manufacturer's problems and requirements; the manufacturer can learn more about the costs, difficulties and needs of the supplier (Trevelen, 1987). The enhanced mutual understanding forms the basis for a greater degree of coordination and cooperation between them, thereby creating a congenial environment for undertaking activities such as joint problem solving, product development, and quality and delivery time improvement. Once the communication links are established, they can be made more efficient by using EDI.

2.5.4.2. Joint Product Development

Close relationship between a manufacturer and its suppliers takes many forms, one of which is joint product development. It implies that manufacturers involve suppliers early in the process of new product design. Motorola involves its suppliers from the beginning when designing a part and seeks their suggestion on how to make it (Magnet, 1994). It is necessary to seek early participation because suppliers know more about their own products and capabilities than the manufacturers and can help find expedient solutions.

Early involvement of suppliers reduces the need to make modifications in designs, thus enabling faster development of new products. Constant interaction between engineers of both sides help resolve design problems and process and material specifications related problems. Often a manufacturer can benefit from a supplier's expertise. A supplier may know how to design a specialized part, minimize the material and manufacturing cost and avert design flaws leading to unreliable performance (Magnet, 1994). Thus, an early input of supplier's expertise could significantly enhance the **changeover flexibility** of the manufacturer, affecting the *mobility* element.

Involving suppliers has some indirect advantages as well. Trevelen (1987) believes that the stability of the relationship between the manufacturer and supplier guarantees volume sales and often encourages a supplier to commit greater resources to long-term research and development, and to a new part production. Also the manufacturer can assist a supplier with resources and technical expertise if it becomes aware of a lack early in the game.

A close relationship allows the manufacturer to utilize the resources of the supplier while developing new products. Involvement of the supplier in new product development and the joint utilization of resources improves the manufacturer's ability to introduce a greater number of new products. This can enhance the manufacturer's *range* element of **changeover flexibility**.

Involving the suppliers in every step from concept through design to manufacturing also accelerates modifications to existing products. This can increase the **modification flexibility** (Macbeth and Ferguson, 1991). Suppliers can help ensure that a modified part can be produced with minimal changes in tooling. In case the required raw material or component is not available, a supplier can suggest alternatives. This allows the manufacturer to easily implement a greater number of modifications to an existing product. The flexibility elements enhanced here would be *range* and *mobility*.

Von Hippel discusses (1986) the relationship between manufacturers and suppliers from a different angle. He explains that *lead users* can provide valuable data to their suppliers about developing new products and services. "*Lead users*" are consumers who require a novel or enhanced product or service much before most consumers in the market and "possess the capability to visualize such needs".

Since lead users of industrial goods can be identified more reliably as compared to lead users of consumer goods, a lead user (manufacturer) is more likely to be a good source of data for its suppliers. A large manufacturer on the leading edge of technology possesses the ability to invest immense resources towards innovating and solving problems. Such lead users (manufacturers) could use their supplier's expertise to find

speedy solutions to some problems and thus shorten their innovation cycle time.

In summary, development of a closer relationship creates the necessary trust and cooperation between a manufacturer and its suppliers. This in turn, allows the utilization of the production capabilities of both parties and facilitates joint development and manufacturing of new products. Seeking advice from suppliers can help a manufacturer to design and develop new products at a faster rate and at a lower cost. The supplier's participation can help a manufacturer to reduce the time needed to introduce new products and gain a competitive advantage. Lead (user) manufacturers at the forefront of technology can fulfil their envisioned needs faster by involving suppliers in their development efforts.

2.5.4.3. Supplier Training

A M-S relationship is considered close when manufacturers start recognizing suppliers as extensions of their own production systems (Hahn et al., 1986). Once a relationship has developed to that level, the manufacturer can start helping the supplier improve or upgrade its capabilities. One of the ways of achieving these objectives is through training the supplier personnel, just as a manufacturer trains its own employees to improve productivity, performance and flexibility.

Dealing with a small network of suppliers means, that any weaknesses in the supplier network will be reflected in the productivity and quality of the manufacturer's product line. This is one of the main reasons why many companies are devoting a greater amount of time and resources towards training their suppliers attain the most efficient

manufacturing and management practices. Many large manufacturers are offering training programs at their suppliers' premises. They are sending their quality control and engineering personnel to the suppliers' plants to provide training, as well as technical assistance in order to bring the product quality up to the manufacturer's standards. A few examples will clarify this concept.

Hay (Jan. and May, 1990) claims that Xerox has established a good relationship with its suppliers. It sponsors training courses for its suppliers on how to reduce setup times and create a better product flow by grouping machines in cells, as well as in quality assurance techniques like Statistical Process Control. At Xerox, a number of people from all areas - engineering to accounting help suppliers as consultants for more intensive one-on-one work. Xerox shares with its suppliers the results of its benchmarking against its competitors, so that its suppliers could learn about their counterparts' lead times, tooling costs, material costs, and overhead rates. Xerox also invites its U.S. and European suppliers to visit and study their Japanese counterparts.

Magnet (1994), while discussing M-S relationship provides an example of Motorola. Motorola selects its suppliers on the basis of shared organizational values. Then it enhances their skills by teaching them Total Quality Management techniques. It even asks suppliers to take courses in cycle time reduction, customer satisfaction, going as far as grading them on these aspects. At the same time Motorola personnel tour its suppliers' plants and grade them on how well they compare to the competitors' suppliers on quality and timeliness. Motorola also encourages its suppliers to analyze how much quality defects add to their costs, so that they see cost-reduction opportunities and increase their

profits. In a similar context, McMillan (1990) adds that Boeing has begun training its suppliers in Statistical Quality Control, and works with them to reduce costs and even involves them early in the development process.

Sheridan (1990) reports that Honda Motor Co. has instituted a "guest-engineer" program for its suppliers. In this program engineers from North American supplier firms are brought to Japan for a short duration, where they work closely with Honda engineers on designing parts that will be eventually produced by them to supply to the Honda division in America.

Training suppliers, however is expensive. For many companies it is prudent to be selective about the type of aid offered. It may also be appropriate to approach this task on a supplier-by-supplier basis or by asking the suppliers to share the cost involved (Hay, May 1990).

This explains why all the above examples involve large firms. It is possible that small and medium size firms have neither the expertise nor the resources to train their suppliers. If some of these firms have such training programs in place, it is not yet recorded by any researcher.

However, it is important to note that training requires considerable time and effort, and the benefits accrued from it might be observed only after a long time. Hence it is possible that small and medium size firms want to know the actual benefits of supplier development programs before making such demanding commitments.

In the context of this study, it is necessary to note that the impact of supplier training on flexibility may not be direct. Nevertheless, educating the supplier to reduce

setup times and cycle times should logically improve the mix, changeover, volume, and delivery flexibility of the firm. Also, training suppliers to produce stable quality would reduce the manufacturer's need to acquire greater material flexibility. But in case of training it is not a priori possible to determine which of the elements of flexibility, range or mobility, is influenced more.

Summing up, the industrial world has long been aware of the benefits of training. However, manufacturers have only recently realized the importance of training their suppliers, distributors and customers. This is because production is an independent activity and a deficiency in one of the links can be quickly felt by the entire chain.

2.5.4.4. Quality and Continuous Improvement Programs

In order to compete, a firm must be able to produce high quality at a reasonable cost. A firm's effort to this end is highly influenced by its suppliers' ability to provide high quality parts. In a close relationship, the manufacturers and suppliers are committed to cooperate in improving quality as well as overall costs (Gentry, 1993). Quality problems could originate in many other areas. For example, improper packaging may affect the quality of incoming parts. Therefore, while improving a supplier's production quality it is essential to improve other capabilities of the supplier as well. Therefore, this section, while discussing supplier quality, will also focus on other areas of suppliers such as planning, packaging, product design, scheduling and transportation.

A few examples will illustrate this dimension of a close relationship. The purchasing department of Honda Motor Co. has appointed 40 full time engineers to work with its suppliers to improve their productivity and quality. In addition to this, another 120 engineers in the quality-control department deal exclusively with incoming parts and supplier quality issues. Honda has also instituted its "*Quality Up*" program targeted at suppliers whose quality is not up to Honda's standards. Suppliers are asked to specify their strategy to improve quality and the resources they are employing towards producing a 100% quality product. Thereafter "special teams" are established as needed to assist these suppliers. Sheridan (1990) reports that these steps have resulted in exceptional quality improvements; 40 of Honda's suppliers regularly send products that are 100% defect-free and 100% on time.

Nissan engineers regularly audit their local suppliers' plants and assist them in every necessary way to improve quality. Assistance is provided in areas of design and process engineering and statistical quality control, in order to detect and minimize quality problems (Ansari and Modarress, 1990). Nissan has also instituted its "*Supplier Quality Assurance*" program that emphasizes pre-production quality planning and detailed process specifications, as well as "part and failure mode effect analysis". Such quality assurance standards are developed and agreed upon with suppliers prior to production. However, all this does not mean that Nissan or Honda has taken charge of its suppliers' quality. The suppliers are still expected to continue to improve process designs, quality control systems and preventive measures (Carr and Treusdale, 1992).

In fact, according to Ansari and Modarress (1990), one of the main reasons a manufacturer strives to improve the quality of its supplier is, that it wants to transfer the function of quality control to the supplier. Once the supplier is successful in meeting the manufacturer's quality specifications, it wants the suppliers to make sure that the quality is built in before the parts leave their plants. This transfer of responsibility allows a manufacturer to significantly reduce the formal inspection of incoming supplies and the delivery can now directly be made to the assembly line. This can reduce the lead time and improve the flexibility of the manufacturer.

It is necessary that while helping suppliers improve their quality, manufacturers should allow them the freedom to make recommendations and discuss problems in the areas of design and quality. This helps manufacturers to get 'things done right the first time', and allow them to develop new products or make modifications in existing products without the usual initial rejects of production. This can increase the **changeover and modification flexibility** of the manufacturer. The flexibility element involved in both types would be *mobility*.

Trevelen (1987) maintains that manufacturing a product correctly the first time could also lead to significant price reductions due to lesser rework and scrap costs. In a close relationship, manufacturers and suppliers can share data on quality, as well as cooperatively design quality control systems that can be used to resolve quality problems. Improved quality parts can reduce the manufacturer's need for material flexibility.

Even in a close relationship there are problems in solving critical quality issues. Quality refers to the conformance of standards. In this case, the standards are set by the

manufacturer and the interpretation of those standards can be subjective. Baxter et al. (1986), consider that differences in interpretation subject to manufacturers' veto can create lapses in good relationship. They suggest a better understanding between the manufacturers and suppliers, as well as greater exchange of quality control data. This can allow suppliers to know the needs of manufacturers better and can help reduce interpretation differences significantly.

Hay (1989) suggests that while improving the supplier's quality, the manufacturer could also teach its suppliers statistical process control techniques, help design transportation routes and reusable packaging, and even help implement JIT manufacturing. Teaching implementation of JIT and efficient transportation and packaging methods can help reduce the lead time of the manufacturer.

An example of a company that tries to improve various capabilities of their suppliers is Nissan. Nissan's Supplier Development Teams visit the suppliers regularly and advice them on matters such as scheduling, planning, product quality, design and performance, and even on problems relating to components for other customers (Carr and Truesdale, 1992). Similarly, Honda provides suppliers technical support in areas such as plastics technology, welding, stamping, and aluminum diecasting (Sheridan, 1990).

However, Carr and Truesdale (1992) argue that continuous improvement programs can create tension between the two parties. Some suppliers find it unreasonable that they should be under constant pressure by the manufacturers to reduce prices throughout the life of the product. Pressure to cut costs may tempt suppliers to allow quality to slip.

In sum, quality is one of the most critical factors in evaluating the manufacturing effectiveness of a firm. A manufacturer's capability to produce high quality products is greatly influenced by its suppliers' ability to supply high quality parts and components. It is necessary, therefore, to not only improve the manufacturer's own quality, but also to improve the quality capability of its suppliers. An improvement in the supply quality provides many benefits including lower costs, greater operational flexibility and fewer rejects.

We have thus discussed four dimensions of a close relationship between manufacturers and suppliers, and tried to review the research to date that argues in its favour. The first dimension discussed was information sharing. Sharing of production schedules facilitates a number of activities such as joint problem solving, joint product development, and improving delivery time; it can also improve the flexibility of the firm. Electronic data interchange is one of the fastest ways to communicate that is gaining popularity.

Joint product development was the second dimension of a close relationship. It requires that a manufacturer involves suppliers early in new product design efforts. Some authors have claimed that an early involvement can increase flexibility providing a vital competitive edge to the manufacturer.

In a close relationship manufacturers become increasingly dependant on a small supplier base. As a result, a deficiency in any of the suppliers can immediately affect the manufacturer's product quality, productivity and flexibility. This critical dependence drives many manufacturers to try to improve the capabilities of the suppliers. One of the

ways to do that is through supplier training programs. The existence of such training programs is the third dimension of a close relationship.

The fourth dimension is quality improvement program that spreads to include supply quality management. Many well-known companies are devoting a lot of time and effort to improving or upgrading the capabilities of their suppliers. One of the focal areas is quality. Many manufacturers are introducing quality improvement programs to monitor the quality of their suppliers, to encourage them to take responsibility of quality control, and to ultimately reduce their inspection costs. Such programs include sharing quality control data, resolving quality problems and at the same time assisting them to upgrade product quality. In addition, manufacturers are also initiating continuous improvement programs for their suppliers to bring about improvement in other interdependent areas such as process control, packaging, transportation, and production costs. These programs are said to improve the quality and flexibility of both the manufacturer and the supplier (Trevelen, 1987; Sheridan, 1990; Ansari and Modarress, 1990).

These four dimensions are thus identified to be critical for a successful close relationship between manufacturers and suppliers, and the preceding discussion has illustrated benefits and ways of implementing them.

2.5.5. Some Other Characteristics of a M-S Relationship

The discussion has so far omitted the negative aspects of a M-S relationship. Many relationships may be close in terms of transactions and communications, but not so in terms of all the four dimensions described above.

A close relationship requires trust between the two parties. Magnet (1994) explains that suppliers often share secret information with their customers. This is especially true in the case of activity-based costing, in which a supplier opens its books to the manufacturer, laying out its cost structure in terms of materials, labour, sales, marketing and other expenses. Such arrangements can be quite demanding. The supplier may find itself vulnerable to pressure of the manufacturers to sell at a fixed percentage over the cost of manufacturing that may not allow for research and development, technical support, and many such activities considered imperative to business success, yet do not show up in the book as variable cost of production. Newman (1989) adds that such constraints may affect the innovativeness of the supplier and discourage the supplier's effort to develop new parts or make modifications. It can eventually affect the **mix and modification flexibility** of the manufacturer.

St. John and Heriot (1993), while supporting the above views, claim that small suppliers are more vulnerable to being pressured by their manufacturer customers to reveal their costs and pricing data. Large manufacturers represent a significant portion (often 100%) of a small supplier's total sales. In such cases, a small supplier can become a virtual captive of the manufacturer, being vulnerable to the manufacturer's growth and powerful negotiating position. The large manufacturers have the clout to force the required product quality and a purchase price acceptable to them. For example, the small supplier is often forced to bear the extra cost of transportation and administration of frequent deliveries in order to fulfil the manufacturer's JIT setup.

McMillan (1990) further adds, that a supplier may invest in tooling in order to produce a special component for its customer (manufacturer). The use of such specialized equipment may make the supplier vulnerable to being pressurised by the manufacturer to decrease prices. In such case, the supplier may have no option but to agree. This may not only affect the profitability of the supplier, but can also affect its ability to invest in new equipment, and space, ultimately jeopardizing the mix, changeover, and volume flexibility of the supplier.

Examples of the above situation include some small Japanese suppliers that supply a limited number of components to a single major manufacturer. Manoochehri (1984), for instance, observes that these suppliers are significantly dependent on their customers for most of their capital needs and their production systems are sometimes even designed specifically to fit the customers' needs. This, of course, makes it difficult for the supplier to produce variety and introduce new or improved product lines.

Similarly, a lure of high future sales volumes from a single customer may induce a supplier to purchase special purpose equipment specifically designed to produce one type of product requested by a manufacturer (Trevelen, 1987). This can significantly reduce the supplier's mix, changeover and modification flexibility.

Manipulating suppliers undermines the true virtues of a close relationship and it is necessary that manufacturers refrain from taking undue advantage of suppliers. On the other hand, it is possible that manufacturers share a healthy close relationship with their suppliers but still face some problems.

Problems of a close relationship:

A close relationship requires a small supplier base and some of the problems may arise due to this small base, as discussed earlier. A small base decreases the purchasing flexibility⁸ of the manufacturer and a close relationship may reduce the manufacturer's options to choose from a number of competitive suppliers (Kim, 1991). By manipulating a greater number of suppliers, the manufacturer may be able to purchase at better prices. Also, according to Hahn et al. (1986), in a competitive market inefficient suppliers would eventually be squeezed out of the market.

If the demand for the manufacturer's products unexpectedly increases, the small supplier network may not be able to cope with the excess demand. This can lead to significant opportunity loss for the manufacturer.

The existence of a long term contract and the mutual agreement to share a long term relationship lead to an absence of competition. Trevelen (1987) is of the view that such an arrangement may tempt the supplier to allow quality to slip in an attempt to cut costs. He also adds that the manufacturer may try to assist the supplier in every possible way, but the manufacturer's efforts are wasted if the supplier is not interested in keeping up with the pace of technology or maintain a good performance. There have been cases in which suppliers have used long term contracts to take advantage of their customers, rather than improve their performance. Many manufacturers, therefore include a clause in their agreement explicitly stating the course of action if the supplier constantly provides low quality or displays gross inefficiency.

⁸ Does not refer to manufacturing flexibility

It is true that there may be some problems in a close relationship. However, a cooperative relationship can provide many benefits to both manufacturers and suppliers.

2.6. Literature Summary

Flexibility which refers to the ability of a manufacturing system to successfully adapt to changing circumstances (Swamidass, 1988) has assumed great significance for manufacturing in the last decade. Manufacturing flexibility is a multi-dimensional concept and has been difficult to measure due to the paucity of research in the field. Fortunately, recent research efforts of Slack (1987), Kumar (1987), Gerwin (1989, 1993) and Upton (1993/94) have made some gains in this direction. This study uses five flexibility types, namely mix, changeover, modification and volume flexibility, as identified by Gerwin (1989) and delivery flexibility as defined by Suarez et al. (1991). These five flexibility types are considered at the system level and seem suitable for the current study of manufacturer-supplier relationship. However, Gerwin's flexibility types or that of Suarez et al. are hard to operationalize. The task has been accomplished by combining the above notions with those suggested by Upton (1994), namely *range* and *mobility*.

Many factors affect the manufacturing flexibility of a firm (Piore & Sabel, 1984; Suarez et al., 1991). One of these factors is manufacturer-supplier relationships. Manufacturers have realized that suppliers can play a significant role in enhancing their ability to produce a reasonably-priced quality product in a short time (Hahn et al., 1990). This acceptance is motivating many manufacturers to develop a closer relationship with their suppliers (Hay, 1990; McMillan, 1990). A few researchers (Trevelen, 1987; Ansari

and Modarress, 1988; Hay, 1990; Hahn et al., 1990; McMillan, 1990; Stalk and Hout, 1990; Gupta et al., 1991; Helper, 1991; Kim, 1991; Suarez et al., 1991; and Gentry, 1993) have studied this trend and have concluded that a better relationship with suppliers can improve the manufacturer's product quality, delivery time and flexibility.

However, the literature in the area of M-S relationship does not delve into the concept of the relationship or attempt to identify relative importance of the different elements of the relationship. In this review the essential points concerning M-S relationship have been extrapolated to some extent and four dimensions of a close M-S relationship have been identified: information sharing, joint product development, supplier training and, quality and continuous improvement programs. We have identified and examined the benefits of these four dimensions for both manufacturers and suppliers, and anticipated their impact on the five flexibility types of the manufacturer.

In addition, some of the problems of a close relationship have also been considered along with the aggravations of a manipulative relationship. But researchers believe that the advantages of a genuine close relationship outweighs any drawbacks.

With this background a conceptual model to determine the effect of a close M-S relationship, as defined by the four dimensions, on the five flexibility types will be developed in the next chapter. Some of the other important aspects of the M-S relationship will also be investigated such that the concept of the relationship is better understood.

CHAPTER 3

RESEARCH QUESTION

The preceding discussion leads us to believe that better M-S relationships have a significant impact on the manufacturing flexibility of a system. Given that little research has been done on linking M-S relationship with manufacturing flexibility, we seek to answer the following question:

What are the effects of a manufacturer-supplier close relationship, defined by four dimensions: information sharing, joint product development, supplier training, and quality improvement programs, on the mix, changeover, modification, volume and delivery flexibility of a manufacturing system?

The following conceptual model forms the basis of this study.

Figure 1 - Conceptual Model

Based on a number of studies and the arguments provided in Chapter 2, certain expectations can be drawn regarding the impact of the four dimensions of a M-S relationship on the five flexibility types. The nature of these impacts is shown in Table 3a below.

Dimensions of Flexibility	Information Sharing	Joint Product Development	Supplier Training	Quality & Cont.Imp. Programs
Mix	+ (M)	o	+ (*)	o
Changeover	+ (M)	+ (R&M)	+ (*)	+ (M)
Modification	+ (M)	+ (R&M)	o	+ (M)
Volume	+ (M)	o	+ (*)	o
Delivery	+ (M)	o	+ (*)	o

Table 3a: Extent of Impact of the four dimensions of a close relationship on the five flexibility types.

List of Abbreviations:

Cont.Imp.= Continuous Improvement

Keys:

+ = positive influence

o = no influence

R = range

M = mobility

* = difficult to identify range and mobility elements

These four dimensions evaluate the ability of the manufacturing function to respond to changes in customer tastes and unexpected capacity and delivery requirements. In order to avoid complexity and to adhere to time limits, the scope of this study is confined to the manufacturing environment. It does not delve into areas such as marketing and distribution.

However, efforts will be made to investigate other important aspects of the M-S relationship such as the level of collaboration between manufacturers and suppliers, the key areas of the relationship and how the relationship is strengthened. We believe that such an examination will lead to a more complete study of the concept of M-S relationship.

With this objective in mind, an instrument has been developed to measure M-S relationship and to test the hypotheses presented in Table 3a.

CHAPTER 4

RESEARCH DESIGN

This chapter addresses the research methodology used in the study. A brief explanation is presented on why a field study was preferred over other methods such as a case study analysis. The data collection method is then discussed followed with consideration of the reliability and validity of the study. The sampling procedure is briefly presented thereafter, followed by the last few sections which examine the procedures used to analyze the data.

A field study was carried out in manufacturing firms in the electronics and telecommunication industries in Ontario and Quebec with sales (1993/94) of over \$50 million (Canadian). The field study option was preferred to a case study for two reasons. In order to achieve greater generalizability, it is necessary to study multiple firms; in a case study only a few firms can be studied. Also, the focus of a case study is usually broad and the approach tends to be in-depth and comprehensive. Studying the M-S relationship in depth would require an examination of the relationship from the supplier's perspective as well. Since the suppliers may be located far from the manufacturing firms, it would be difficult to conduct an in-depth study. Finally, since the variables in this study are fairly well-defined there was no need for an open-ended approach.

The electronics and telecommunication industries have been selected for the study because they are well represented in Ontario and Quebec. Moreover, these industries have short product life cycles and rapid innovations. As a result, they are under constant

pressure to rapidly introduce a great variety of products. Thus, manufacturers in these industries require various types of manufacturing flexibility including mix, changeover, modification, volume and delivery flexibility. Furthermore, limiting the study to two industries provides a natural control over some extraneous variables and the macroeconomic conditions are roughly the same for all firms in the industry.

The sample was comprised of firms only with high sales because it is believed that large firms have more resources to train their suppliers, to use sophisticated technology to communicate with them and to possess the technical expertise to help suppliers improve product quality and other capabilities.

The data for the field study were collected through structured interviews. The questions were designed with the guidance of two experienced researchers. Two executives from each firm - one from purchasing and the other from manufacturing - were interviewed. In cases where two executives did not participate, the vice presidents of manufacturing (two cases) or the heads of the supply management team (two cases) were interviewed. The interview technique provided the opportunity to explain, clarify and seek the views of the executives.

Two respondents were preferred for a couple of reasons. First, a purchasing executive may have the required information about a firm's relationship with its suppliers, but may not know how it affects the manufacturing operations. The production manager, on the other hand, may have adequate knowledge about the manufacturing process, but may have little idea of the intensity of the firm's relationship with its suppliers.

The second reason is that a single respondent's account of organizational factors may be biased. Overreporting or underreporting of certain phenomena is likely to occur due to factors such as the respondent's position, job satisfaction and other characteristics (McClintock, Brannen, and Maynard-Moody, 1979; Patchen, 1963; Seidler, 1974). Different respondents may base their conclusions on different information and attach different weights to different information. Also, differences may occur due to information sources available, and the length of time the respondent has been in the organization (Phillips, 1981; Houston & Sudman, 1975; Seidler, 1974). To the extent such factors influence the respondent's judgement there could be a low degree of conformance between a respondent's account and the organizational reality. Phillips (1981) warns that surveying a single respondent to measure organizational characteristics is not a reliable method. He believes that gathering data from multiple informants (at least two) for every construct under study could significantly improve the reliability and validity of the study. In this study, thus, responses were sought from two executives and the average was used for the analysis.

4.1. The Interview Structure

The objective of the interview questions was to determine the type of relationship existing between manufacturers and suppliers, as well as to measure the impact of a close relationship on the five types of flexibility. The impact was measured by using three types of questions: binary, open ended and 5-point Likert-like scales.

The interview schedule consisted of 25 questions and was divided into five sections corresponding to each of the four dimensions namely information sharing, joint product development, supplier training and quality improvement programs, while the last section consisted of a few demographic questions. The following table provides a summary of the questions.

PART #	QUESTION #	PERTAINING TO
1	5 - 10	Information Sharing
	10	Extent of the impact of information sharing on the five flexibility types
2	11 - 13	Joint Product Development
	13	Extent of the impact of joint product development on the five flexibility types
3	14 - 18	Supplier Training
	17	Extent of the impact of supplier training on quality, productivity, setup time, manufacturing process capability and delivery time
4	19 - 21	Quality Improvement Programs
	21	Extent of the impact of quality improvement programs on the five flexibility types
5	1 - 4 22 - 25	Demographic Questions

Table 4a: Interview Structure

The questions were designed in a manner so as to best isolate the impact of a close M-S relationship on the five flexibility types. The questions, cover letter and the approval of the University Ethics Committee are included in Appendix B.

Reliability and Validity:

Reliability is the degree to which a procedure for measuring accurately measures the object under investigation and produces similar outcomes when it is repeated (Carmines and Zeller, 1979, p. 11). *Cronbach's (1951) coefficient alpha* was used to assess the reliability of the measurement scales. Interviewing two respondents from each firm also contributed to increasing the reliability of the study. Cronbach's alpha was determined for information sharing, joint product development and quality improvement programs. Since, supplier training does not include a multi-item scale and measures different constructs, Cronbach's alpha was not used for it. The result is given below:

Constructs	Cronbach's Alpha
Information Sharing	0.79
Joint Product Development	0.83
Quality Improvement Programs	0.89

The high value of alphas indicate reasonable reliability of the scales.

Validity refers to the crucial relationship between concept and indicator (Carmines and Zeller, 1979, p. 12). It is the degree to which an instrument measures what it intends to measure. We will be considering three types of validity: content validity, internal validity and external validity.

Content Validity refers to the thoroughness or completeness of the measurement device. In other words, does the survey instrument cover the major dimensions of the subject matter under assessment (Adams & Schvaneveldt, 1985). It is difficult to establish content validity for management concepts since the full domain of such concepts is rarely

agreed upon (Baker, 1988). Only subjective evaluation by proficient individuals can ensure that relevant items are included and irrelevant items are excluded from the study (Gerwin and Kolodny, 1992). Gronlund (1968) suggests that in order to establish content validity, a group of specialists be consulted and the items to be measured be selected on logical grounds. This research was executed with the help and guidance of two specialists (Dr. V.Kumar & Dr. S.Pal) who are experienced researchers. Moreover, a pretest was done before administering the interviews and suggestions from external practitioners were incorporated in the final interview. Further, all constructs were devised on the basis of an extensive literature search and seem to be supported by prominent researchers in this field.

Internal Validity refers to whether the observed change in the dependent variables can be attributed to independent variables or possibly to extraneous variables which are not under the control of the researcher (Adams & Schvaneveldt, 1985). In this study, internal validity was gained by designing the questionnaire in such a manner so as to best isolate the impact of a strong M-S relationship on the five flexibility types, and by controlling the sample. The questionnaire asked respondents to assess only one particular dimension of the relationship at a time, and consider the impact of only this dimension on the five flexibility types.

External Validity refers to generalizability or representativeness of the general findings. A list of fifty-five firms, which formed the population for this study, was obtained from *Industry Canada*. Given that all of these firms were contacted for this research, the population formed the sample of the study. Thus, the results can be said to

have high external validity for the subpopulation of firms willing to participate in the data collection process.

4.2. Sampling Procedure

The population consisted of all electronics and telecommunication firms in Ontario and Quebec with sales of over 50 million dollars (Canadian) in 1993/94. *Industry Canada* provided a list of fifty-five firms. One firm from the list was randomly selected from the Ottawa region and was used as a pretest. Based on the suggestions given by the respondent from this firm, minor changes were made to the interview structure.

The purchasing and manufacturing executives of the 54 companies were contacted by telephone and the nature of the study was explained to them and their participation was sought. Twenty-three agreed to participate. Thirty-five interviews with respondents of these firms were administered, each lasting for approximately forty-five minutes to an hour.

All respondents were assured confidentiality and they consented to the objectives of the study. A copy of the letter of consent used for the study can be found in Appendix B.

The gist of the views expressed by respondents were noted down during the interview and were expanded immediately after the interview. On completion of the interview, the responses were reviewed. Any omissions or problems were immediately resolved.

4.3. Data Analysis

The responses included both qualitative and quantitative data. All of the data were checked for normality. In addition, the logarithms of two variables (items 7 and 19) were used in order to normalize them.

Stepwise multiple regression was used with the quantitative data. The independent variables used in the regression analysis were the measures of information sharing, joint product development, supplier training and quality improvement programs. The dependent variables were the five flexibility types each having two elements, range and mobility for all dimensions except supplier training. In the case of supplier training the dependent variables were the extent of improvement in supplier's ability to produce better quality, improvement in setup time, productivity, manufacturing process capability and delivery time (Hay, Jan. and May 1990, McMillan 1990). Thus, thirty-five stepwise regressions were performed, ten each for information sharing, joint product development and quality improvement programs and five for supplier training.

The sample size was small, but stepwise multiple regression was deemed to be one of the most powerful tests providing maximum information for this study. It eliminates the least useful predictor and considers the most significant predictors at every stage. Thus, it is possible to estimate the kind of information sharing, joint improvement efforts or the kind of training that affects a given type of flexibility the most. Non-parametric tests would have overlooked significant amount of information.

For the qualitative data, frequencies were calculated in most cases. The data were subjective answers such as percentage of managers preferring some method of assistance to another, using certain kind of training, achieving some advantages or perceiving certain dimensions of the relationship to be important. Most of the qualitative data are presented in a tabular form followed by a brief explanation.

4.4. Independent Variables

Once the data were collected, checked and tabulated, a correlation analysis was performed among all items concerning M-S relationship, so that the highly correlated items could be collapsed into one. Stevens (1992) suggest the use of a small number of independent variables in multiple regression analysis. High correlation among the items would also indicate possible collinearity problems which could cause otherwise significant variables in multiple regression analysis to appear to be unimportant.

The correlation matrix of M-S items showed high correlation among several sets of items. For example, item 5 (suppliers having access to manufacturer's production schedule) and item 6 (information regarding subsequent changes in them) were correlated ($r = 0.6483$, $p = .001$). Similarly, item 8 (exchange of technical specifications) and item 9 (quality data between manufacturers and suppliers) were correlated. A complete list of correlations appears below:

Highly Correlated Items

Information Sharing (IS)

IS of production schedules (Q5)	AND	IS of quality data (Q9)
Changes in production schedules (Q6)		
Exchange of technical specifications (Q8)		
IS of production schedules (Q5)	AND	Changes in production schedules (Q6)

Joint Product Development

IS of technical specifications (Q8)	AND	Seeking supplier expertise (Q12)
Involving suppliers in product design (Q11)		
IS of technical specifications (Q8)	AND	Involving suppliers in product design (Q11)

Supplier Training

Training in production planning	AND	JIT (Just-in-time)
Training through seminars		
Years - Formal training	AND	JIT, production planning
Formal training	AND	Production, quality
Informal training	AND	Quality

Quality & Continuous Improvement Programs

Manufacturers Assisting
Suppliers in:

Production scheduling (Q20a)	AND	Planning Process (Q20b)
Product Design (Q20d)		
Packaging (Q20e)		
Transportation (Q20f)		
Product Design (Q20d), Packaging (Q20e)	AND	Quality (Q20c)
Packaging (Q20e), Transportation (Q20f)	AND	Product Design (Q20d)
Production Scheduling (Q20a), Transportation (Q20f)	AND	Packaging (Q20e)

Although many items were statistically correlated, only one correlation made sense - items 5 and 6. They are access to production schedule and reporting of subsequent changes in them respectively. These two variables were averaged and called "CIN 5&6" referring to a composite index of items 5 and 6. No other correlation, for example information sharing regarding technical specifications (Q8) and exchanging data regarding quality (Q9), logically makes sense. For another example, combining correlated variables such as improving supplier's planning process, product design and packaging would not bear any practical merit; nor would the correlation between exchanging technical specifications and seeking the expertise of suppliers. If all the correlated variables were to be aggregated we would have little idea as to what kind of information sharing, training programs, or capability improvement leads to greater flexibility. A clearer picture

is likely to emerge if all the items were viewed separately.

Nevertheless, in order to satisfy the conditions of regression analysis, composite indices of the collinear variables were used (Method 1)⁹. The results of these analyses were compared with those of stepwise regression using all the items separately except items 5 and 6 (Method 2)¹⁰. No significant differences resulted. Some examples are presented in Table 4b.

Description of regression	Adjusted R ² (Method 1)	Adjusted R ² (Method 2)
IS & Mix - range	0.388	0.388
IS & Changeover - mobility	0.600	0.649
JPD & Modification - range	0.538	0.564
QIP & Mix - mobility	0.818	0.872
QIP & Volume - range	0.844	0.886

Table 4b: Comparison of two regression approaches, 1 with aggregated variables and 2 with unaggregated items

IS = Information Sharing
JPD = Joint Product Development
QIP = Quality Improvement Programs

As can be seen from the above table, the correlation between variables measuring information sharing and mix-range flexibility as determined by the R² was 0.388 by using method 1 as well as method 2. Similarly, the impact of information sharing on

⁹ Regression using composite indices of all collinear variables

¹⁰ Regression using all variables separately except items 5 & 6

changeover-mobility was 0.60 by method 1 and 0.649 by method 2. Since, results from the two methods did not differ significantly Method 2 was chosen to obtain maximum information.

To summarize, thirty-five managers from twenty-three electronics and telecommunication firms in Ontario and Quebec were interviewed face to face through a structured questionnaire. Although some of the independent variables were correlated, only two of them were collapsed into one in order to obtain a clearer picture of the results. The collected data were both qualitative and quantitative. Frequencies were calculated for the qualitative data followed by brief comments. Stepwise multiple regressions were used to examine the quantitative data.

CHAPTER 5

RESULTS

The results are presented in three sections. In section one the manufacturer's supplier base is discussed. Suppliers were divided into two groups, Group 1 representing suppliers of standardized parts and Group 2 consisting of suppliers producing customized parts. Only Group 2 suppliers were considered in this study. In addition, the manufacturer's sourcing policy for Group 2 suppliers are probed.

In section two, the longest section of this chapter, the expected and actual impact of the four dimensions of a close relationship on the five flexibility types are compared. There was a reasonable correspondence between the expected and actual observations: 22 out of a total 30 expectations match.

As anticipated, the first dimension, information sharing, was found to have a strong positive impact on three of the five flexibility types. Most manufacturers surveyed share significant amount of information in areas of production schedules and quality with their suppliers.

Contrary to expectations, the second dimension, joint product development, was found to show a strong positive impact only on the mobility element of modification flexibility. The survey also found that majority of the manufacturers seek their suppliers' expertise and significantly involve them in new product development efforts. The fourth dimension, quality and continuous improvement programs, also has a strong positive impact on four of the five flexibility types. A large percentage of the manufacturers help

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their suppliers in areas of quality, production scheduling and planning mainly by offering expertise and arranging meetings.

One of the major findings of the study is that the mobility element of flexibility, which refers to the speed at which changes can be accomplished, is influenced the most by the above-mentioned three dimensions.

Supplier training, the third dimension, was found to positively influence the supplier's ability to produce better quality as well as to improve setup time, manufacturing processes and delivery time. Most manufacturers acknowledge the benefits of supplier training. Furthermore, it was observed that the benefits of combined formal/informal training were greater than only informal training.

In section three, some of the other significant findings of the study are presented. These findings include managers' views of factors that have contributed most towards developing a better relationship with suppliers as well as how manufacturers recognize the supplier's contribution to the growth of their firms. In addition, some of the chance findings of the study have been summarized in this section.

5.1. Supplier Base

In this study, the Group 1 suppliers provide standardized parts and Group 2 suppliers provide specialized custom-made parts or manufacture entire subsystems. The number of suppliers for a firm seems to depend on the type of products the firm manufactures. If a firm manufactures products with many standard parts (e.g. standard IC's, cables, resistors etc.) it would have a high number of Group 1 suppliers. On the

other hand, if a firm manufactures very special-purpose products with high content of custom-made parts (e.g. special switches, printed circuit boards, custom built cables, high resolution circuits) it would have more Group 2 suppliers. Manufacturers would have little to gain by developing a closer relationship (as defined in this study) with suppliers belonging to the Group 1 category. Therefore, this research considered only Group 2 suppliers with whom manufacturers would want to develop a meaningful relationship. The number of Group 2 suppliers for each of the firms surveyed varied significantly and are presented below.

Number of firms surveyed	23
Mean number of Group 2 suppliers	151.3
Standard Deviation	237.6
Minimum number of Group 2 suppliers	5
Maximum number of Group 2 suppliers	1000

Table 5a: The Sample

5.1.1. Sourcing Commitments

Approximately 60% of manufacturers have long-term agreements (more than two years) with more than one-third of their Group 2 suppliers. Further, 63% of manufacturers purchase more than half of their requirements of parts and components from one or two sources; under 5% of the manufacturers have no long-term agreements with their suppliers and use more than two sources for most of their purchases. The summary of these findings are presented in Table 5b.

Sourcing Activity	Percentage of manufacturers
Long term agreements with over 30% of suppliers	59.1
Long term arrangements with none	4.5
Purchasing more than 50% of requirements from 1 or 2 suppliers	63.6
Purchasing from multiple sources (more than 2 suppliers)	4.5

Table 5b: Sourcing operations of Manufacturers

5.2. Effects of the Four Dimensions of a Close Relationship with Suppliers on the Flexibility of the Manufacturer

In Chapter 3, the expected effects of a close relationship with suppliers on the flexibility of the manufacturer were discussed. The expected and actual outcomes of the study are presented in Table 5c.

Dimensions of Flexibility	Information Sharing		Joint Product Development		Quality & Cont. Imp. Programs	
	Hyp.	Obs.	Hyp.	Obs.	Hyp.	Obs.
Mix	R $\Rightarrow$	o	o	o	o	o
	M $\Rightarrow$	+	+	o	o	+
Changeover	R $\Rightarrow$	o	o	+	o	o
	M $\Rightarrow$	+	+	+	o	+
Modification	R $\Rightarrow$	o	o	+	o	o
	M $\Rightarrow$	+	o	+	+	+
Volume	R $\Rightarrow$	o	+	o	o	o
	M $\Rightarrow$	+	+	o	o	o
Delivery	R $\Rightarrow$	o	o	o	o	+
	M $\Rightarrow$	+	o	o	o	o

Table 5c: A Comparison between the expected and actual impacts of three dimensions of a close relationship on the five flexibility types.

List of Abbreviations:

Hyp. = Hypothesized

Obs. = Observed

Cont.Imp. = Continuous Improvement

Keys:

+

 = positive influence

o

 = no influence

R

 = range

M

 = mobility

As can be seen, 22 out of a total 30 expectations match. In a majority of the cases, the mobility element of flexibility is affected the most by the three dimensions.

As explained before, it is difficult to measure the direct influence of supplier training on the five flexibility types, because logically, the impact of supplier training on the flexibility of the manufacturer is not direct. Thus, it was decided to examine the manufacturers' perception of whether or not training of suppliers had any effect on improving the quality, setup time, productivity, manufacturing process capability and delivery times of the suppliers. Table 5d shows that the overall effect of such training is positive. That is, training of suppliers generally has led to an improvement in the supplier's ability to produce better quality; it also improved their setup time, manufacturing process capability and delivery time. An improvement in these supplier capabilities has the potential to enhance the changeover, modification and delivery flexibility of the manufacturer. Furthermore, it is not possible to establish which element of flexibility, range or mobility is affected most.

The effects on the chosen measures are summarized below.

Supplier Capabilities	Direction of Impact
Ability to produce better quality	+
Setup time	+
Productivity	o
Manufacturing process capability	+
Delivery time	+

Table 5d: Results showing the impact of supplier training on improvement in supplier capabilities as reported by manufacturers

The findings concerning the effects of the four dimensions will be discussed in the same order as presented in the literature review: that is 1) information sharing 2) joint product development 3) supplier training and 4) quality and continuous improvement programs.

5.2.1. Information Sharing

The importance of information sharing has been discussed in detail in a previous chapter. It was described as the "pillar" of a M-S relationship. This research focussed on information sharing regarding production schedules, technical specifications/designs and quality data. A summary of some of the results is presented in Table 5e.

Total number of firms = 23

Area of Information Sharing	% Yes	% No
Production Schedules	39.1	13.0
Schedule Changes	60.9	4.3
EDI	8.7	47.8
Technical Specifications	30.4	17.4
Quality control data	65.2	0

Table 5e: Areas of Information Sharing

65% of the manufacturers regularly share quality data with their suppliers and over 60% of them provide immediate information regarding any changes in production schedules to their suppliers. Many managers indicated that sharing production schedules

is critical in meeting delivery times.

Interestingly, the manufacturers sharing a considerable amount of information in one category also share a great deal of information in other categories as well. For example, most firms which share information concerning production schedules and changes in these schedules also share substantial information regarding technical specifications and quality control.

It is surprising that in spite of extensive automation and computerization, especially in the telecommunications and electronics industry, EDI is not used extensively by manufacturers. (Only 8.7% of manufacturers surveyed use EDI.) In the literature review the importance of EDI was stressed; several authors (Biby, 1992; De Toni et al., 1994) reported the use of EDI for exchanging design information and feedback. Our data do not support this, possibly due to the fact that EDI still appears to be a new technology as pointed out by Banerjee and Goldhar (1992). Moreover, EDI is only one of the many information technologies that can be used to communicate electronically. Some managers confirmed that they do not use EDI, but communicate through other means such as E-mail and on-line computer systems. Also, a couple of managers indicated that some of their suppliers are frequently in-house and company employees directly communicate with these suppliers. Nevertheless, some managers do plan to implement EDI in the coming year.

Table 5f shows the statistical impact of information sharing on the range and mobility element of mix, changeover, modification, volume and delivery flexibility.

		t values			
Flexibility	Adjusted R ²	CIN 5&6	EDI	I-8	I-9
Mix-range	0.39	0.9858	0.6186	0.0020	0.1165
Mix-mobility	0.75	0.0000	0.0594	0.0003	0.0090
Changeover-range	0.22	0.0144	0.9824	0.1748	0.5448
Changeover-mobility	0.63	0.0000	0.1674	0.2255	0.7627
Modification-range	0.19	0.1547	0.2869	0.0229	0.6278
Modification-mobility	0.46	0.0020	0.0305	0.1013	0.6350
Volume-range	0.68	0.0025	0.3611	0.0011	0.0790
Volume-mobility	0.77	0.0073	0.0416	0.0001	0.0890
Delivery-range	0.57	0.0026	0.9765	0.0449	0.2396
Delivery-mobility	0.52	0.0048	0.3303	0.0477	0.9767

Table 5f: Results of Regression Analysis showing the impact of information sharing on the different flexibility types

CIN 5&6 = Composite index of questions 5 and 6 which refer to production schedules and changes in them

EDI = Information sharing through Electronic Data Interchange

I-8 = Information sharing regarding designs and technical specifications

I-9 = Information exchange regarding quality data

All t values significant at 0.05 level

A cut-off value of 0.60¹¹ has been selected for the adjusted¹² R^2 in order to accept an effect which is considered to be more practical. It should be borne in mind that selecting a high¹³ cut-off value for the R^2 reduces the Type I error at the expense of the Type II error. A *Type II error* involves accepting a null hypothesis when it should be rejected. That is, it is possible for a researcher to commit a Type II error by accepting the null hypothesis, when the variation is actually due to true and reliable variation.

On the other hand, a *Type I error* involves rejecting a true null hypothesis. In this case, the researcher decides that there are real differences between the two experimental groups, when the differences are actually due to chance variation (Adams & Schvaneveldt, 1985). This error can be reduced by selecting a small value of p (probability). The selected probability of Type I error, α , is called the significance level of the test. Selecting a 5 percent α level means that the test was constructed to allow a 5 percent chance of Type I error (Smith, 1985). Many researchers are sceptical unless the p value is much smaller than 0.05. Hence, when the probability level is set at 0.01, it means that there is only a 1% chance of making a Type I error. By attempting to reduce a Type I error in this analysis, the probability of making a Type II error has been increased (Adams & Schvaneveldt, 1985).

Selecting a very low α level reduces the possibility of a sampling error. Also, a low α level would reduce the possibility of the effect of external factors on flexibility in this study. Moreover, the R^2 that has been used to establish an effect in this study reflects a more precise impact of a close M-S relationship on the five flexibility types.

5.2.1.1. Effect of Information Sharing on Mix-Mobility flexibility

An adjusted¹⁴ R^2 of 0.75 in Table 5f, shows that the items measuring information sharing positively affect the mobility element of flexibility. This result corresponds with our expected outcome.

¹¹ According to Stevens (1992), a researcher dealing in data reflecting human perception is fortunate to observe an R^2 as high as 0.70.

¹² For a small sample size, the adjusted R^2 is a more reliable estimate (Stevens, J., 1992).

¹³ Can be obtained from the list of tables for the 0.01 and 0.05 levels of significance (Snedecor and Cochran, *Statistical Methods*, The Iowa State University Press, 6th edition, 1967).

¹⁴ For a small sample size, the adjusted R^2 is a more reliable estimate (Stevens J., 1992).

Banerjee and Goldhar (1992) argue that sharing production schedules provides manufacturers and suppliers timely information regarding each other's needs. Under a JIT environment, this facilitates frequent purchases in small lots, thus allowing the manufacturer to switch from producing one variety to another quickly. The regression equation shows that the items measuring communication of production schedules and changes in production schedules, as well as the use of EDI, are strong predictors of mix-mobility flexibility. Other strong predictors include sharing technical specifications and quality data.

5.2.1.2. Effect of Information Sharing on Changeover-Mobility

In the literature review, a strong positive impact of information sharing on the mobility element of changeover flexibility was predicted. If manufacturers promptly provide suppliers with new designs, suppliers will have sufficient time to make required changes in their production process. This, in turn, can reduce the manufacturer's time for introducing new products, thereby improving changeover-mobility.

Our results show a strong impact of information sharing on changeover-mobility flexibility reflected by an adjusted R^2 of 0.63. The results also indicate that information sharing regarding production schedules and changes in these schedules are strong predictors of changeover-mobility flexibility.

5.2.1.3. Effect of Information Sharing on Modification-Mobility

The expected effect on this flexibility type was positive. However, Table 5f shows the adjusted R^2 as 0.459, indicating no significant effect.

When minor modifications are implemented in the manufacturer's product line, simultaneous changes in the parts or components supplied could also be required. If information regarding the modified parts are provided on time, the time needed by the manufacturer to implement modifications in the product line can be reduced. This could improve the manufacturer's modification-mobility flexibility.

However, as one of the managers pointed out, many modifications do not need new or modified parts. In such cases, manufacturers would seldom require the assistance of their suppliers in modification and the issue of information sharing will not arise.

5.2.1.4. Effect of Information Sharing on Volume-range

No significant effect was expected in this case but the study found a positive effect on the range element of volume flexibility as indicated by an adjusted R^2 of 0.68.

The probable reason for such an outcome is that sharing production schedules and subsequent changes in these schedules provides suppliers with prompt information regarding the needs of the manufacturer. Such reliable exchange of information could encourage the manufacturer to accommodate greater fluctuations in production volume. This was the argument of one of the interviewees.

Correspondingly, regression results indicate that information sharing regarding production schedules and changes in these schedules, as well as information sharing of

designs and technical specifications, are strong predictors of volume-range flexibility.

5.2.1.5. Effect of Information Sharing on Volume-mobility

As expected, information sharing has a significant positive effect on the mobility element of volume flexibility as indicated by an adjusted R^2 of 0.77. Prompt exchange of information between manufacturers and suppliers regarding production schedules and any changes in these schedules, can allow suppliers to meet manufacturer's demands with short notice. This could enhance the volume-mobility flexibility of the manufacturer.

The statistical results support this argument, indicating production schedules and changes in these schedules, technical specifications and information exchange through EDI as strong predictors of volume-mobility flexibility.

5.2.1.6. Effect of Information Sharing on Delivery-mobility

The effect of information sharing on the mobility element of delivery flexibility was the only result which indicated the presence of a possible outlier. The adjusted R^2 was 0.52, showing no effect which was contrary to the expected outcome. However, the Cook's distance in this case was greater than 1, signifying the presence of an outlier. Graphing the Cook's distance revealed an outlier (Case number 5), yet visual inspection of the questionnaire did not show any peculiar responses. As a result, it was decided to perform a Weisberg (1982) test to determine if a Cook's distance of 1.0808 was a statistically significant deviation (overall alpha = 0.05). The formula used is:

$$t_i = r_i \sqrt{\frac{n - k^1 - 1}{n - k^1 - r_i^2}}$$

$$t_i = 1.085372$$

Since the observed value is less than the critical value of 3.52¹⁵, there is no significant deviation and therefore we accepted the regression results with the Cook's distance of 1.08.

Exchanging information regarding production schedules should allow manufacturers to shorten their own delivery times. One probable reason for the finding of no significant effect on this flexibility is that the manufacturer's ability to deliver on short lead times depends not only on good information exchange with suppliers, but also on many other factors such as the manufacturer's own scheduling expertise, production equipment or transportation abilities.

5.2.2. Joint Product Development

Joint product development is the second dimension of a close relationship. This dimension involves joint utilization of the capabilities and expertise of manufacturers and suppliers, and facilitates the joint development and manufacturing of new products.

¹⁵ Listed in the table of critical values for Weisberg test. Found in most statistics books (e.g. Stevens J., 1992).

Almost 70% of manufacturers seek their suppliers' expertise for improving the performance of a product while it is in production. In addition, over 60% of manufacturers indicated that they involve some of their suppliers in new product development, allow suppliers to influence designs, and seek suppliers' participation from conception through design to manufacturing. This is a very high percentage considering the level of trust and commitment such an activity requires.

Some managers even consulted with their suppliers on how to reduce costs. Any reductions achieved were shared equally between manufacturers and suppliers. In some cases, suppliers were allowed to change tolerance level of parts as long as this did not affect the quality of parts supplied. Thus, suppliers have considerable freedom to take decisions regarding manufacturing, and are also appreciated for sharing their expertise with manufacturers.

In the literature review, it was hypothesized that joint product development efforts between manufacturers and suppliers would positively affect the changeover and modification flexibility of the manufacturer. The statistics of the survey are presented in Table 5g. An examination of the 't' values reveal that information sharing regarding designs and technical specifications, and involving suppliers in new product development efforts are strong areas of the dimension of joint product development.

		t values		
Flexibility	Adjusted R ²	I-8	I-11	I-12
Mix-range	0.34	0.0020	0.1580	0.1439
Mix-mobility	0.53	0.0192	0.0403	0.6248
Changeover-range	0.47	0.2626	0.0002	0.1921
Changeover-mobility	0.48	0.0648	0.0002	0.0937
Modification-range	0.56	0.0316	0.9308	0.0239
Modification-mobility	0.60	0.0000	0.0591	0.0574
Volume-range	0.44	0.0563	0.6620	0.0008
Volume-mobility	0.39	0.0757	0.2955	0.0019
Delivery-range	0.46	0.1203	0.2589	0.0004
Delivery-mobility	0.48	0.0859	0.9098	0.0002

Table 5g: Results of regression analysis showing the impact of joint product development on the different flexibility types

I-8 = Information sharing regarding designs and technical specifications

I-11 = Involvement of suppliers in new product development

I-12 = Seeking supplier expertise

5.2.2.1. Effect of Joint Product Development on Changeover-range

Involvement of suppliers in new product development and the joint utilization of resources improves the manufacturer's ability to introduce a greater number of new

products. This can enhance the manufacturer's range element of changeover flexibility. However, contrary to the expected outcome, an adjusted R^2 of 0.47 shows no significant effect.

It seems that the ability of the manufacturer to make a number of design changes, or to introduce new products, is more heavily dependent on the manufacturer's own setup time, process technology and in-house engineers. Since the supplier has no control over the manufacturer's operations, it can contribute only to a certain extent in enhancing the manufacturer's changeover-range flexibility. In fact, four managers indicated no pressure to introduce greater number of new products in order to compete successfully in their industry.

5.2.2.2. Effect of Joint Product Development on Changeover-mobility

We had expected a strong positive effect of joint product development on the mobility element of changeover flexibility. However, an adjusted R^2 of 0.48 shows no significant effect. We gathered from the literature that involving suppliers early in the design phase should allow the manufacturer to enhance the pace of new product development and increase changeover-mobility flexibility (Macbeth and Ferguson, 1991).

A low significance could be due to the fact that the responsibility for developing new products rests primarily on in-house engineers and the process technology being used by the manufacturer; the suppliers can only provide expertise for certain components that they manufacture. As a result, even though suppliers may be involved early, this may not necessarily lead to the quick development of new products.

As stated previously, four managers indicated no pressure to introduce new products in the industry in which they were competing.

5.2.2.3. Effect of Joint Product Development on Modification-range

Contrary to the expected outcome, an adjusted R^2 of 0.56 reveals no significant effect of joint product development on the range element of modification flexibility.

Seeking the expertise of suppliers and involving them early in the design phase should allow manufacturers to implement a greater number of modifications in existing products (Macbeth and Ferguson, 1991). However, not every modification in the manufacturer's product requires simultaneous changes in the parts or components produced by the suppliers. Trevelen (1987) argues that closer links between the manufacturer and the supplier could persuade the manufacturer to consider the impact of its own product design changes on the design of the items purchased from the supplier. The manufacturer would then ensure that its own modifications lead to limited changes or no changes in the supplied parts. As a result, it is possible that the managers surveyed perceived a small contribution on the part of the suppliers towards increasing modification-range flexibility.

5.2.2.4. Effect of Joint Product Development on Modification-mobility

As expected, the effect of joint product development on the mobility element of modification flexibility was positively significant, with an adjusted R^2 of 0.60.

Macbeth and Ferguson (1991) claim that involving suppliers early in product design, and seeking their expertise wherever possible, should allow manufacturers to make quick modifications to existing products.

Our study supports the above assertion. Results of the regression analysis show that sharing information regarding designs and technical specifications, and involving suppliers in product design, are strong predictors of modification-mobility flexibility.

Our previous argument that a close relationship obliges manufacturers to be more accommodating as regards modifications in suppliers' parts, does not imply that suppliers would never be asked to make any modifications. If and when suppliers are asked to make modifications, these could be implemented promptly, thereby enhancing the modification-mobility flexibility of the manufacturer.

5.2.3. Supplier Training

Supplier training is the third dimension. In the case of supplier training, it was considered difficult and impractical to measure a direct relationship between training suppliers and the effect of such training on the flexibility of the manufacturer. Nevertheless, an attempt was made to explore how training suppliers improves the suppliers' product quality, setup time, productivity, manufacturing process and delivery time. Suppliers' performance on these criteria could then be used to establish a link between them and flexibility of the manufacturer. It is also important to remember that it was the manufacturers that were surveyed and not their suppliers. As a result, it is possible that the responding managers did not have adequate or reliable information

regarding the impact of supplier training on the different abilities of the suppliers. It is therefore advisable to exercise caution in interpreting the results of supplier training.

A regression analysis shows that factors such as type of training (formal and informal), or number of years such training programs have been in place have no significant influence on the supplier's setup time, productivity, manufacturing process capability, delivery time or ability to produce better quality products.

However, the kind of formal and informal training programs seems to have significant influence on the suppliers' abilities. The area in which the training is provided is considered to be more important than how the training is being given, that is, formally or informally. It is logical to assume that if a manufacturer wishes to improve the quality of the supplier's output, it would provide training in areas of quality improvement. Thus, we decided to determine the areas in which manufacturers were providing training to suppliers and ran a regression analysis to determine its effect on supplier capabilities. The areas of training were put into five different categories:

1. Quality training: Eleven manufacturers have training in areas of quality for their suppliers. These include training in ISO 9000, quality systems, SPC (Statistical Process Control) and TQM (Total Quality Management).
2. Production methods: Nine manufacturers have training programs aimed at improving the production methods of their suppliers. Such training includes technical specialist providing on-the-job training, CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) training, manufacturing process training and fundamentals of geometric dimensioning and tolerance.

3. **Production Planning:** Four manufacturers provide training in areas of scheduling, strategic/production planning and logistics.
4. **JIT:** Three manufacturers provide training on JIT and this includes training in areas of inventory management and Kanban.
5. **Supplier seminars:** Three manufacturers arrange seminars and conferences providing formal training to their suppliers.

Other kinds of training include manufacturers providing an on-site tour to suppliers in order for them to observe processes, finished products and problems their parts were causing during manufacturing. This provides the suppliers with a better idea of how change in configuration, design or raw materials could improve the quality and manufacturability of their parts. Some manufacturers also provide training on value engineering, company values and goals, cost reduction, solving specific problems, configuration management, and on the culture of their firms.

Most of the training is in different areas of manufacturing such as SPC, TQM, CAD/CAM, processes, production planning, JIT and value engineering. The majority of the training was provided by manufacturing personnel, and only in some cases people from other departments were involved. Also, sometimes services of outside experts were used and some suppliers were provided with training software.

The statistical results are presented in Table 5h and discussed below.

Abilities	Adjusted R ²	t values					
		I15	QLT	PRD	PPN	JIT	SEM
Better quality	0.65	.580	.000	.770	.291	.143	.649
Setup time	0.76	.512	.560	.010	.433	.000	.237
Productivity	0.42	.272	.385	.091	.007	.529	1.0
Mnfg.process capability	0.73	.416	.551	.000	.456	.010	.827
Delivery time	0.74	.004	.196	.000	.688	.002	.478

Table 5h: Results of Regression Analysis showing the impact of supplier training programs on the different flexibility types

Mnfg. = Manufacturing
 Adj.R² = Adjusted R square
 I15 = Number of years training instituted
 QLT = Training in areas of quality
 PRD = Training in production methods
 PPN = Training in production planning
 JIT = Training in just-in-time techniques
 SEM = Training through seminars

5.2.3.1. Effect of Supplier Training on the supplier's ability to produce better quality parts and components

Training suppliers in areas of quality ought to improve the supplier's product quality. The supporting data on training in quality show the strongest effect, with an adjusted R² of 0.65, on the supplier's ability to produce better quality parts.

11 out of 17 manufacturers imparting training to suppliers agreed that it has significantly improved the quality of incoming parts.

5.2.3.2. Effect of Supplier Training on the supplier's setup time

Case studies by two researchers (Magnet 1994, Hay 1990) indicate that training suppliers in production techniques (CAD/CAM and JIT system), and other manufacturing processes, can lead to a significant improvement in the supplier's setup time.

The above view is supported by the regression of an adjusted R^2 of 0.76. Training in JIT and production methods were found to be the strongest predictors.

5.2.3.3. Effect of Supplier Training on supplier's productivity

An adjusted R^2 of 0.42 indicates no significant effect of supplier training on improving productivity. One probable explanation is that increase in productivity is heavily dependent on type of equipment used by suppliers or the setup time required for different components made for manufacturers.

5.2.3.4. Effect of Supplier Training on the supplier's manufacturing process capability

Researchers, as well as managers, have indicated that training suppliers in production techniques has resulted in significant improvement in the supplier's manufacturing process capability.

An adjusted R^2 of 0.73 supports this notion. The regression equation indicates that training in production methods and JIT are the strongest predictors of supplier manufacturing process capability.

5.2.3.5. Effect of Supplier Training on the supplier's delivery time

An adjusted R^2 of 0.74 shows a significant positive effect of training on a supplier's delivery time. Many manufacturers reported improved delivery times from their suppliers and attributed the same to supplier training programs.

Based on the regression equation, training in production methods, JIT, and training period were found to be strong predictors.

In sum, an improvement in supplier's quality, setup time, manufacturing process capability and delivery time could enhance the changeover, modification and delivery flexibility of the manufacturer.

5.2.3.6. Formal and Informal Training

Formal training programs are more structured and usually imparted to a group of suppliers. It requires greater amount of planning and expertise on the part of the manufacturer. Such training could be directed towards improving a specific area of a group of key suppliers. Informal training on the other hand, requires less planning on the part of the manufacturer and could be imparted to a few suppliers, or even one supplier at a time. Such training could be in any area, depending on the need of the supplier or suppliers.

In one section of the questionnaire, manufacturers were asked to provide information on the different supplier training programs instituted by them, and the benefits of such training. These findings are discussed below.

10 out of 23 firms surveyed (43.5%) provide some type of formal training programs for their suppliers and 17 out of 23 (73.9%) informally train their suppliers. 6 manufacturers who do not informally train their suppliers, have in fact, no training programs at all. The results are summarized in Table 5i.

Type of Training	Yes	No
Formal Training	43.5%	56.6%
Informal Training	73.9%	26.1%

Description	Type of Training	
	Informal	Formal
Manufacturers Training	17	10
Minimum number of years	2	2
Maximum number of years	15	8
Mean	8.18	4
More than 5 years	11	N/C
More than 3 years	N/C	5

Table 5i: Supplier Training

N/C = Not Computed

Over 43% of manufacturers have instituted formal and informal supplier training programs. All manufacturers with formal training programs also reported informal programs. But the reverse did not hold, as the Table 5i clearly shows. Those firms which have formal programs would first introduce informal training programs, and then a

structured formal training program covering a large percentage of suppliers. However, informal training would still continue as suppliers would need assistance in specific areas for which formal training may not be suitable.

Among those suppliers who received informal training, the minimum number was 2 years of training while the maximum was 15 years. In addition, over 64% of the manufacturers have offered informal training programs for more than five years. Thus, it seems that the majority of the manufacturers and suppliers have positive views of training programs. It was decided to calculate the number of manufacturers offering informal training for more than five years, because this type of training is not a very new concept. Moreover, we wanted to ascertain the percentage of manufacturers imparting informal training for more than five years which can be considered a reasonably long period.

Similarly, the minimum number of years manufacturers have been formally training their suppliers is 2 while the maximum is 8 years. 50% of the manufacturers have implemented formal training programs for more than three years. These figures seem to indicate a trend towards more structured training programs and towards targeting an increasing number of suppliers. Formal training seems to be a fairly new concept, and we decided to identify the percentage of manufacturers imparting such training for more than three years, since it is a reasonable time period for manufacturers to better know how to impart such training and realize their benefits.

5.2.3.7. Benefits of training

If manufacturers receive no benefits they would not train their suppliers. In this section, the benefits, as perceived by the manufacturers, of having both formal and informal training programs, and of having only informal training programs for their suppliers are reported.

Benefits of Formal and Informal training

Ten manufacturers offer both formal and informal training programs to their suppliers. Of these, nine reported an improvement in quality and a reduction in defects, leading to lower inspection costs. Out of these nine, one manufacturing manager added that as a result of formal/informal training, over 98% of in-coming parts were defect free. Similarly, another manager claimed that 92% of the parts required no incoming inspection. Some of these manufacturers also agreed that superior quality has significantly reduced scrap and rework costs.

Five manufacturers who indicated an improvement in quality also reported better "on-time delivery" from their suppliers. Four manufacturers out of ten reported reductions in costs, three of which also indicated an improvement in quality. One manufacturer confirmed that costs of procurement were reduced from \$54 per \$1000 of purchases to under \$15 per \$1000. Two manufacturers reported reduction in costs, as well as improvement in delivery times from suppliers.

Four manufacture. ; claimed that training has resulted in sound understanding by suppliers of their needs and expectations. Two maintained that training had improved

communication with suppliers, reduced inventory and helped foster a closer relationship with suppliers. For one manufacturer, training had led to faster development of the best possible design, as well as changes in new designs.

Other reported benefits of formal/informal training included increased level of trust between manufacturers and suppliers, higher productivity, and faster transactions and facilitating implementation of JIT practises.

Benefits of informal training

Seven manufacturers have only informal training programs for their suppliers. Three of them reported improved delivery times from their suppliers and asserted that training had led to a greater understanding by suppliers of their requirements. Two of the manufacturers who reported better delivery times also reported improvement in quality of parts received. Other reported benefits of informal training included lower costs, reduction in lead times and an in-depth understanding of supplier's abilities.

Based on interviews on this topic, a conclusion was reached that the benefits of instituting both formal and informal training programs are greater than the benefits of having only formal or informal programs. 90% of the manufacturers implementing both training programs reported an improvement in quality versus only 28.5% for manufacturers implementing only informal training programs.

The analyses above lend support to the regression results. The statistical analysis seems to indicate that training suppliers has significantly enhanced the suppliers' product quality, setup time, manufacturing process capability and delivery times. These findings are in agreement with the opinions expressed by the managers interviewed.

5.2.4. Quality & Continuous Improvement Programs

Quality is one of the most critical factors in evaluating the manufacturing effectiveness of firms. One of the causes of poor quality can be traced to suppliers. Therefore, any quality improvement program must also address the supplier's quality. Further, since quality is affected by many related processes, it is necessary to help suppliers in - not just manufacturing processes -but also in other areas such as scheduling, process planning, product design, packaging and transportation. Improvement in these areas of suppliers could, in turn, result in an overall improvement of the manufacturer's operational capabilities.

Manufacturers can offer their assistance to suppliers in several ways. In Chapter 2, three methods of helping suppliers have been identified, namely assistance through formal training programs or special courses, arranging meetings and conferences, and offering expertise as needed. The specific areas in which manufacturers assist their suppliers are highlighted in Table 5j.

Areas of Help	number of cases	% helping significantly	% not helping
Quality problems	23	60.9	0
Production scheduling	17	23.5	0
Planning Process	16	37.5	0
Quality	23	34.8	0
Product Design	22	18.2	0
Packaging	18	22.2	5.6
Transportation	16	31.3	12.5

Table 5j: Areas in which manufacturers help suppliers

Over 60% of the manufacturers offer considerable help to suppliers in solving their quality problems. Approximately 35% of the manufacturers help the majority of their suppliers improve their planning process and quality. None of the manufacturers surveyed failed to help their suppliers in quality issues, production scheduling, product design and planning.

From the literature we concluded that quality and continuous improvement programs significantly affect changeover and modification flexibility. However, the empirical results reveal some interesting contradictions.

Flex.	Adj. R ²	t values						
		I19	I20A	I20B	I20C	I20D	I20E	I20F
Mix-rng	0.31	.558	.538	.022	.533	.889	.228	.641
Mix-mob	0.72	.191	.981	.000	.787	.079	.336	.621
Chng-rng	0.34	.378	.692	.016	.733	.510	.698	.333
Chng-mob	0.76	.014	.947	.005	.708	.643	.760	.151
Mod-rng	0.29	.254	.566	.426	.873	.027	.247	.971
Mod-mob	0.60	.963	.524	.001	.882	.089	.547	.204
Vol-rng	0.44	.063	.249	.369	.234	.698	.007	.680
Vol-mob	0.57	.072	.789	.001	.841	.706	.403	.512
Del-rng	0.83	.005	.035	.946	.106	.383	.381	.328
Del-mob	0.56	.072	.001	.401	.973	.762	.927	.470

Table 5k: Results of Regression Analysis showing the impact of quality & continuous improvement programs on the different flexibility types

Flex. = Flexibility Type

Adj.= Adjusted

rng = range

mob = mobility

Chng = Changeover

Mod = Modification

Vol = Volume

Del = Delivery

I19 = Solving suppliers' quality problems

Helping Suppliers in:

I20A = Production scheduling

I20B = Planning Process

I20C = Quality

I20D = Product Design

I20E = Packaging

I20F = Transportation

5.2.4.1. Effect of Quality & Continuous Improvement Programs on Mix-mobility

Contrary to expectations, the effect of quality and continuous improvement programs on the mobility element of mix flexibility seems significant ($R^2 = 0.72$).

One manager said that helping suppliers plan and design their products and components allowed manufacturers to subcontract more jobs to their suppliers. Frequent deliveries in small lots of more subassembled goods allows the manufacturer to quickly switch from producing one variety to another.

Helping suppliers in their planning process and product design were found to be the strongest predictors of mix-mobility.

5.2.4.2. Effect of Quality & Continuous Improvement Programs on Changeover-mobility

An adjusted R^2 of 0.76 supports our expectation of a significant effect of quality and continuous improvement programs on the mobility element of changeover flexibility. As discussed in the literature review, helping suppliers in areas of quality leads to fewer rejects for the manufacturer, allowing it to develop new products much faster without the usual initial rejects of production.

The regression equation indicates that helping suppliers in their planning process and with quality problems are the strongest predictors. Planning process is also a significant predictor because suppliers may need assistance in planning their production process, especially if they are asked to produce new parts with few initial rejects.

5.2.4.3. Effect of Quality & Continuous Improvement Programs on Modification-mobility

As hypothesized, quality and continuous improvement programs significantly affect the mobility element of modification flexibility. This is reflected in an adjusted R^2 of 0.60. When manufacturers help suppliers in areas of product design, they can make quick modifications in parts required by the manufacturer. This, in turn, allows manufacturers to make quick modifications to their own product line.

Our analysis shows that assisting suppliers in product design and planning process plays an important part in influencing modification-mobility. Helping suppliers plan their production process ensures that there is a smooth flow of modified parts with very few initial rejects.

5.2.4.4 Effect of Quality & Continuous Improvement Programs on Delivery-range

Contrary to expectations, the effect of quality and continuous improvement programs on the range element of delivery flexibility seems significant (adjusted $R^2 = 0.83$). When manufacturers assist suppliers in planning schedules and processes, both parties are able to tune their production processes more to each other's needs. Better quality and coordination between the two sides encourages the manufacturer to make greater number of changes in its own production schedules, thereby improving its delivery-range.

The regression equation shows that helping suppliers in production scheduling, quality and planning are the strongest predictors of delivery-range flexibility.

5.2.4.5. Most Popular Methods of Help

The number of manufacturers providing help, in different areas, to suppliers, and the three methods by which such help is provided, are represented in Table 51. Many manufacturers use a combination of all three methods in order to assist suppliers.

	Methods of Help		
Capabilities	Through formal training programs or special courses	By arranging meetings or conferences	By offering expertise as needed
Production Scheduling	1	16	10
Planning Process	4	14	11
Quality	8	17	21
Product Design	2	15	21
Packaging	3	7	17
Transportation	2	6	11

Table 51: Methods of Helping Suppliers

Table 51 clearly shows that the most popular method of helping suppliers is by offering expertise as needed. The least popular method seems to be formal training or special courses. These findings correspond to the results obtained from "Supplier Training", in which it was found that a greater number of manufacturers offer informal

training rather than formal training to their suppliers. One of the ways of imparting informal training is through offering expertise as needed.

We can also conclude that manufacturers provide maximum help in improving the quality and product design of their suppliers. A total of 21 out of 23 manufacturers help their suppliers in areas of quality and product design. Production scheduling, planning and packaging also seem to be quite important areas of help. The low priority given to transportation could be due to the use of a third party by manufacturers and suppliers, which is in most cases a transportation company for the movement of goods and services.

Furthermore, in most cases, manufacturers who help a large segment of their suppliers use all three methods of assistance, namely formal training or special courses, arranging conferences and offering expertise as needed.

In short, the most popular method of helping suppliers improve their various capabilities is by offering expertise as needed. The second most popular method is assistance through arranging meetings and conferences. Helping suppliers through formal training programs or special courses is a distant third.

It can be observed from the data and the results from the study of the last two dimensions, namely supplier training and quality improvement programs, that there is a substantial overlap in the conceptualization of these two dimensions.

5.3. Findings From Open-ended Questions

The survey included a few open-ended questions aimed at obtaining information which is neither quantitative nor capable of explaining the relationship between

manufacturers and suppliers. This includes factors contributing towards developing a better M-S relationship according to the managers and the means by which manufacturers recognize their supplier's contribution. In addition, some of the chance findings of the present study which are based on comments made by some managers, are presented in this section.

5.3.1. Factors Contributing Towards Developing a Better Relationship With Suppliers

Managers were asked to choose among the four dimensions (information sharing, joint product development, supplier training and quality improvement efforts) the dimensions which contributed most towards developing a better relationship with suppliers. In cases where managers listed more than one factor, all additional factors have also been listed, since the question did not specifically ask for only one contributing factor but all factors that have positively contributed towards the development of a closer relationship.

Dimension	Number of managers selecting the dimension
Information Sharing	17
Joint Product Development	11
Supplier Training	6
Quality Improvement Programs	16

Table 5m: Managers' Rankings of the Four Dimensions

"Information Sharing" was chosen by 17 managers (34%), which is the highest ranking among the four dimensions . This conforms with views expressed in the literature review, as well as the results of the regression analysis, in which variables measuring information sharing show a significant affect on several flexibility types. These results confirm the notion that information sharing is the "pillar" of a close M-S relationship.

"Quality Improvement Programs" was chosen by 16 managers (32%), which is the second highest ranking. This also conforms with the results of the regression analysis in which quality and continuous improvement efforts show a strong effect on manufacturing flexibility.

"Joint Product Development" was chosen by 11 managers (22%). Supporting this ranking is the statistical result which does not show as significant an effect on flexibility as the above two dimensions.

"Supplier Training" was least common, selected by only 6 managers (12%). This may be due to the fact that six manufacturers have no training programs for their suppliers and therefore never considered supplier training to be one of the contributing factors. Moreover, benefits of supplier training are indirect and difficult to comprehend. In addition, the data seem to show a significant overlap between the concept of training and continuous improvement programs. Since the survey instrument did not explicitly define the concept of training, it is possible that the managers got confused and included some of the information on training in the dimension of continuous improvement programs. Thus, although the regression analysis has indicated a strong impact of supplier training on improving some of the supplier's capabilities, it was not found to be important

by the managers.

Other Factors Reported by Managers

An attempt was also made to uncover additional factors that may have helped improve the firms' relationship with their suppliers. 15 managers out of 35 could not think of any additional factors. However, 9 managers concurred that "trust and more openness" has improved relationship with their suppliers. 3 managers considered "long term agreements" to be important, while 2 managers thought "tracking supplier performance on the basis of quality, cost, responsiveness and delivery" has helped their relationship with suppliers.

Factors that were picked by individual managers but not supported by others include -single sourcing, speed, small supply base, best price and service, risk sharing, financial and contractual agreements, good payment policies, regular visits from both sides, increased cooperation, supplier selection and continuing evaluation.

5.3.2. Recognizing Supplier's Contribution

13 out of 23 (56.5%) manufacturers recognize their suppliers' contribution to the growth of their firms. In other words, they use some mechanism to encourage their suppliers and make them feel that their work is valuable and appreciated.

Some of the most popular methods used by manufacturers to recognize their supplier's contribution are:

1. Eight manufacturers recognized their supplier's contribution by presenting awards such as "Supplier of the Year" and "Best Vendor Award". One manufacturer invited its two

best suppliers to a golf banquet. Another classified its suppliers in different categories such as gold, red etc., "gold" signifying excellent performance and "red" denoting poor performance in terms of quality, delivery, cost or innovativeness. Based on these categories, the company presented its five best suppliers awards for excellence.

2. Four manufacturers presented a type of "Certificate of Recognition" to their suppliers for providing good quality, on-time deliveries and good service.

3. Five manufacturers reviewed their suppliers' performance annually and presented "Supplier Qualification Certificates" to those who qualified. Such certificates provided suppliers certain advantages, such as absence of formal inspection, long-term contracts, higher volume orders, access to shop floor, product designs and processes of the manufacturer.

Thus, a number of manufacturers have started recognizing their supplier's contribution through different means, some of which seem fairly innovative.

5.3.3. Selected Comments from Managers

Only managers of ten companies could afford the time to expand on their firm's relationship with suppliers and on the reason for their need to develop a good relationship or to pay no special attention to this issue. A detailed account of each company's views can be found in Appendix C. Here a selected few comments which add to the insight gained in this study are presented.

One of the ten firms provides the suppliers with specialized equipment and extra tooling enabling them to produce the specialized parts according to specifications. The

company appreciates the suggestions of its suppliers regarding cost reduction. Any benefits as a result of such recommendations are shared by both the firm and its suppliers. A second firm engaged in a similar relationship reported significant savings in inventory carrying costs as a result of a better relationship with suppliers.

The managers of another company claimed total involvement of their suppliers in the company's operations. The suppliers of this firm have full access to the company's production schedule. By being on-line, the suppliers can even make changes in the company's production schedules. On-line training programs enable this firm's suppliers to even train their respective suppliers. This company offers expertise to even its suppliers' suppliers. In addition, suppliers are allowed greater freedom in manufacturing parts and components and are even authorized to change tolerance specifications as long as this does not affect quality.

One of the firms employs an 8-Discipline¹⁶ program aimed at improving various capabilities of suppliers, such as quality, delivery and manufacturing processes.

Only a few companies had a different perspective on M-S relationship. These companies are involved in producing unique, large and expensive products, with a very low annual volume. In addition, they expressed no need to increase their mix, volume or changeover flexibility. One of these companies mainly bids on government contracts and the government frequently provides the company with a list of vendors. As a result, the list changes with every new contract and the company generally uses the vendor list to buy from the cheapest source. Such a policy is not conducive to developing a closer

¹⁶ A similar program is instituted by Ford.

relationship with suppliers.

The strategy of another such company is to manufacture every component in-house. Only when there is a shortage of capacity or lack of expertise/capability does there arise a need for subcontracting. In other words, the company discourages development of a close relationship with its suppliers. The management's strategy is to compete on delivery and not on cost. The company believes that suppliers tend to delay and that the best strategy for meeting on-time delivery is to try to manufacture all requirements in-house. As a result, the company does not wish to depend on suppliers.

Based on these interesting views, a supplementary analysis was done excluding these two firms. However, analysis indicated that the firms had no significant effect on the overall results.

The managers of one of the companies acknowledged the importance of greater involvement of suppliers, and agreed that they did not share a close relationship with their suppliers.

Most managers' opinions reported above support our findings that a better relationship with suppliers provides significant benefits to the manufacturers. However, only a few manufacturers have indicated that the need to develop a close relationship with suppliers depends on their policies and manufacturing strategies. The need to develop a close relationship seems to also depend on the type of products the firm produces and the generally competitive environment of the industry.

5.4. Results Summary

The bottom line of the results, then, is that a close relationship with suppliers generally improves the operational capabilities of the manufacturer. The capabilities examined here, of course, were the five flexibility types. On comparison of the actual findings with the expected results, we found that 22 out of a total 30 expectations match. Out of the four dimensions, information sharing and quality improvement programs were found to have the strongest impact across all flexibility types. The four dimensions were found to have maximum impact on the *mobility* element of flexibility, which relates to the speed at which the changes can be achieved.

The main highlights of the results are:

- A majority of the manufacturers purchase more than half of their requirements from one or two sources.
- Sharing production schedules and quality data is considered critical by most manufacturers. However, EDI, as an information technology, is used by only a few manufacturers. The dimension of information sharing was found to significantly improve the manufacturer's mix, changeover and volume flexibility.
- The majority of the manufacturers seek their suppliers' expertise for improving product performance, and involve some of their suppliers in new product development activities. However, contrary to expectations, joint product development did not show a strong positive impact on enhancing the manufacturer's changeover flexibility. The mobility element of modification flexibility was the only type of flexibility that was positively affected by this dimension.

- Quality and continuous improvement programs were found to significantly improve the manufacturer's mobility element of all the flexibility types except volume. Manufacturers were also found to provide maximum help to their suppliers in areas of planning, quality, product design and scheduling. Such help is provided through a variety of means such as offering formal training, arranging conferences, or providing expertise as needed.
- Most manufacturers' opinions seem to indicate that supplier training has a positive impact on improving the supplier's product quality, setup time, manufacturing processes and delivery time. A greater number of manufacturers provide their suppliers with informal training, rather than formal training, or a combination of both. It was also found that those manufacturers having only informal training programs for their suppliers may not enjoy as many benefits as those firms which implement both types of training programs, formal and informal.
- Out of the four dimensions, managers considered information sharing and quality improvement programs to be the more important factors in their relationship with suppliers than joint product development or supplier training programs. Although, supplier training was found to be a very important aspect of an M-S relationship, manufacturers have not exploited its full potential, especially in the area of imparting formal training programs.
- Majority of the manufacturers recognize their suppliers' contribution through different means such as "Supplier of the Year", "Best Vendor Award", "Certificate of Recognition", and "Supplier Qualification Certificates".

Most of the results conform with our expectations based on the literature review. Moreover, additional views provided by some of the managers also support the findings of the study. Managers interviewed maintain that greater cooperation with suppliers has provided them with a number of benefits, including significant cost advantages and timely deliveries. However, it is to be borne in mind that a company's policies, manufacturing strategy, and the line of products manufactured by it could be important determinants in influencing a firm's decision to develop close cooperation with its suppliers.

In spite of the above view, results strongly reiterate the importance of a close M-S relationship, emphasized time and again in the literature review, as well as the benefits this relationship provides manufacturers, particularly in terms of increased flexibility.

CHAPTER 6

CONCLUSIONS

The present study substantiates the notion that suppliers are an integral part of manufacturing organizations, and if a firm wishes to be flexible and succeed in the new time-based competition, it needs to increase the involvement of its suppliers in its manufacturing operations.

Although there are several factors that affect manufacturing flexibility, this study focusses on one important factor, namely M-S relationship. This study investigated the relationship along four dimensions, namely information sharing, joint product development, supplier training, and quality and continuous improvement programs.

The literature on M-S relationship (Trevelen, 1987; Ansari and Modarress, 1988; Hay, Jan. and May, 1990; Hahn et al., 1990; McMillan, 1990; Kim, 1991; Suarez et al., 1991; and Gentry, 1993) argues that a better relationship with suppliers can improve the manufacturer's product quality, delivery time and flexibility. However, no strong empirical evidence establishing a link between M-S relationship and operational flexibility existed before this study.

The findings of this study, which are extensively discussed in Chapter 5, corroborate with literature in this field, and strongly suggest that a closer M-S relationship provides several benefits to manufacturers, one of which is increased manufacturing flexibility. The effect of five flexibility types on M-S relationship was examined; mix,

changeover, modification, volume and delivery flexibility.

Most responding managers' views on current practices in industry also support the above notion. Managers have emphasized that greater cooperation with suppliers has provided them several benefits, including significant cost advantages and timely deliveries.

Findings of the regression analysis, as well as the qualitative responses from the managers, indicate the importance of the four dimensions of an M-S relationship identified in this study. It seems that the two dimensions, namely *information sharing*, especially in the area of production schedules and quality data, and *continuous improvement programs* are critical elements of the M-S relationship.

Although, most manufacturers seek their suppliers' expertise for improving product performance, as well as developing new products, manufacturers do not believe that such involvement has significantly improved their changeover and modification flexibility.

A majority of the manufacturers were found to offer considerable expertise to their suppliers in areas of planning, quality, product design and scheduling. The area of supplier training is an important dimension of this relationship and seems to have a positive impact on improving the supplier's product quality and other capabilities. Manufacturers seem to derive more benefits from providing both types of training to their suppliers, formal and informal, rather than informal training alone.

A M-S relationship has four important dimensions, and information sharing is the pillar of this relationship. A casual relationship between manufacturers and suppliers may not provide as many benefits as a relationship which is conscientiously and strategically

developed along the four dimensions identified in this study.

6.1. Implications of the Study

This study gives us a more detailed understanding of the role of suppliers in influencing the operational capabilities of the manufacturer. It outlines the benefits manufacturers gain through a closer M-S relationship, specifically in terms of increased manufacturing flexibility. It also provides guidelines to manufacturers on the process of developing a better relationship with suppliers. Managers can use a cooperative relationship with suppliers, along with other factors such as information systems, production equipment, worker skills and quality control, in order to significantly increase flexibility.

The study also identifies the important dimensions in which the M-S relationship can be developed. Managers can choose the set of dimensions that best suit their company policies and manufacturing strategies. The study can assist managers in identifying the areas of the relationship that need to be strengthened in order to enhance a required type of flexibility.

The study can also help manufacturers evaluate their relationship with suppliers along the four dimensions, and guide them on how to further strengthen this relationship. The information could help managers answer questions such as:

- * How can I increase the benefits to my firm by developing a closer relationship with my suppliers?

* Which flexibility do I want and how can the four dimensions be possibly used to achieve them?

The measures developed to evaluate the different types of flexibility will be of interest to academics as well as to managers who can utilize these measures as a practical tool in industry.

The study can also be used to develop benchmarks in the area of M-S relationship. Managers can use these benchmarks to determine their position on the relationship scale.

6.2. Limitations

The sample size was small with only 23 companies included in this study. Therefore, it may be difficult to generalize the results. However, the companies interviewed covered the industrial belt in Ontario and Quebec, and therefore are believed to constitute a fair representation of industry in these areas, and to some extent, across Canada, given that the majority of Canada's manufacturing sector is in Ontario and Quebec.

The second limitation of this study is the use of the subjective measures of the impact of the four dimensions on the five flexibility types. The respondents' experiences, as well as personal biases, could have influenced the responses concerning the subjective measures. This bias was reduced to a certain extent by interviewing two respondents from each firm.

The instrument developed to measure the impact of the four dimensions on the five flexibility types could not explicitly capture the direct impact of the dimension of

supplier training. The reason for this, is that, the suppliers were not part of the study and their views concerning the impact of training on the suppliers' operations were not considered. On the other hand, the manufacturing managers were asked to provide information about improvement in different abilities of the suppliers who in fact may not have the complete information about the effect of training suppliers on improvement in suppliers' abilities. Therefore, it is necessary to exercise caution in interpreting the results of supplier training. Moreover, there was a significant overlap between the concept of training and continuous improvement programs. The design of the survey instrument could have possibly confused the managers and they may have included some of the information on training in the dimension of continuous improvement programs. Defining training more explicitly could have resulted in managers precisely understanding the concept of training, and providing clearer information.

Some extraneous factors could inhibit or promote manufacturing flexibility. As discussed in Chapter 2, factors such as worker skills, layout, production equipment, information systems, management practices and quality control can also simultaneously contribute to enhancing manufacturing flexibility. On the other hand, factors such as demand, labour laws, unions and availability of components/spare parts could inhibit the realization of manufacturing flexibility. These factors were not considered in this study.

Although it is difficult to separate the impact of all factors, an attempt was made, using the questionnaire, to isolate their impact from the impact of close M-S relationship on the five flexibility types. The survey instrument was designed in a way to make sure that respondents were assessing only one particular dimension of the relationship at a

time, and were specifically asked to consider the impact of only this dimension on the five flexibility types.

6.3. Future Research

The primary objective of this study was to measure the impact of a close relationship with suppliers on the flexibility of the manufacturer in the electronics and telecommunications industry. A similar study could also be conducted in other industries, and even in other countries, in order to examine how firms in other industries or countries develop their relationship with suppliers. It is possible that the maturity or infancy of certain industries could lead to differences in the impact of suppliers on the manufacturers' operations. Also, differences in technological development or economic environment could lead to a different impact of suppliers on the manufacturer's operational flexibility.

Future research could attempt to identify dimensions other than information sharing, joint product development, supplier training and quality improvement programs, which help in defining a close relationship between manufacturers and suppliers. Such dimensions could include long term agreements, single sourcing, risk sharing, and financial agreements.

Furthermore, a study could be done to explore the impact of a close relationship on other flexibility types. The model used in this study to measure M-S relationship and manufacturing flexibility could be enhanced in areas such as supplier training and measuring its effect on the flexibility of the manufacturer. This research had not predicted

a significant overlap in the two dimensions, supplier training and continuous improvement programs. Future research should consider this overlap and perhaps combine these two dimensions in order to create only three instead of four distinct dimensions of a M-S close relationship.

This study measured the impact of a close relationship on improvements in the manufacturer's abilities. However, improvements in these abilities could lead to an adverse effect on the supplier. For example, investing in special purpose equipments to produce parts for manufacturers may enhance the manufacturer's flexibility, but at the same time adversely affect the profitability of the supplier, as well as its ability to invest in new equipment, and research and development activities. A study could be conducted from the supplier's point of view on how such a relationship affects the supplier's operations.

APPENDIX A

Partial list of the types and definitions of flexibility proposed in the literature.

Flexibility Type	Definition
Author: Buzacott (1982)	
State Flexibility	Ability of the system to process a wide variety of parts of assemblies without intervention from outside to change the system.
Job Flexibility	The ability of the system to cope with changes in the jobs to be processed.
Machine Flexibility	The ability of the system to cope with changes and disturbances at the machine and work stations.
Author: Brown (1984)	
Machine Flexibility	Ease of modifying production of given parts.
Process Flexibility	Ability to produce the same parts in different ways.
Product Flexibility	Ability to switch production easily to different products.
Routing Flexibility	Ability to continue production despite process breakdowns.
Volume Flexibility	Efficiency over a range of production volumes.

Expansion Flexibility	Ability to add to production capacity easily.
Operation Flexibility	Ability to sequence production in alternate ways.
Production Flexibility	Ability to produce a large variety of products.

Author: Jaikumar (1984)

Process Flexibility	Ability to reroute a part when a machine is down.
Program Flexibility	Ability to run the system unattended.
Product Flexibility	The total incremental value of new products that can be fabricated within the system for a defined cost of new fixtures, tools and parts programming.

Author: Slack (1989)

Product Flexibility	The range of and the ability to change the products capable of being produced.
Mix Flexibility	The range of and ability to change the products currently being produced.
Volume Flexibility	The range of and ability to change the aggregated output for a given mix.
Delivery Flexibility	The range of and ability to change delivery times.

Author: Schmenner (1990)

Product mix Flexibility	Ability to produce with a mix of products.
New product Flexibility	Ability to add a new product to the existing mix.
Volume Flexibility	Ability to change the level of output.

Author: Sethi & Sethi (1990)

Machine Flexibility	Types of operations machine can perform without requiring a prohibitive effort in switching from one operation to another.
Material Handling Flexibility	Ability of the system to move different parts efficiently.
Operation Flexibility	Ability of a part to be produced in a different way.
Process Flexibility	Ability of the system to produce a set of part types without major setups.
Product Flexibility	Ease with which new parts can be added or substituted for existing parts.
Routing Flexibility	Ability to produce a part by alternate routes through the system.
Volume Flexibility	Ability of the system to be operated profitably at different overall output levels.
Expansion Flexibility	Ease with which capacity and capability of the system can be increased when needed.

Program Flexibility	Ability of the system to virtually run unattended for long periods.
Production Flexibility	Universe of part types that the manufacturing system can produce without adding major capital equipment.
Market Flexibility	Ease with which the manufacturing system can adapt to changing market uncertainties.

Author: Gerwin (1992)

Mix Flexibility	Ability to process a number of different products at the same time.
Changeover Flexibility	Ability to deal with additions to and deletions from the product mix.
Modification Flexibility	Ability of a process to accommodate functional product changes.
Rerouting Flexibility	Degree to which the operating sequence of a particular product flow can be changed.
Volume Flexibility	Ease with which changes in aggregate production can be made.
Material Flexibility	Ability to handle variations in parts and subassemblies.
Sequencing Flexibility	Ability to rearrange the order in which the product mix is being produced.

APPENDIX B

COPY OF THE COVER LETTER

Date: _____

Name of manager
Position of Manager
Company name
Company address

Dear manager,

I am a graduate student in the School of Business at Carleton University. As a requirement of my Master's degree, I am writing a thesis in the area of manufacturing excellence.

A number of researchers have suggested that good relations with suppliers have helped many manufacturing firms in a number of ways. However, there is some controversy about such assertions. As a topic of my thesis, I have chosen to study the effect of such relations on one aspect of manufacturing operation - flexibility.

Your answers to a few questions would be of tremendous help to me. The questions ask for your estimates and opinions; answers to the best of your recollection will serve my purpose. The questionnaire takes about half an hour to complete.

Your answers will be treated as **strictly confidential**. Any published data will be only in aggregate or statistical form and would neither identify you nor your company. The results of the study would help us understand more fully the relative importance of the different ways in which *manufacturer-supplier relationship* can be improved, and how these dimensions could be utilized to increase the flexibility of the firm. Since you are entitled to an executive version of the study, you may use my results for benchmarking purposes as well.

If you have questions, please feel free to contact me or my supervisors. I thank you in advance for your participation.

Yours sincerely,

Khalil N. Viraney

COPY OF THE CONSENT FORM

CONSENT FORM

This is a consent form which is required by the Carleton University Ethics Committee in order to ensure that the participants in this study are aware of the following information:

- * The **aim** of this study is to evaluate the relationship between manufacturers and suppliers and to measure the impact of this relationship on the firm's manufacturing capability. This study is part of the requirement for my Master's degree.
- * The participants will be asked to complete a questionnaire pertaining to the kind of relationship they have with their suppliers and its impact on their manufacturing operations. The interview will be conducted on the company premises and will take about **half an hour** to complete.
- * All information will be treated as **strictly confidential** and any published data will only be in aggregate or statistical form.
- * Participants have the right to withdraw at any time or not answer all questions.
- * Participants will have the option of receiving a **summary of the results**.
- * Any questions or concerns can be directed to the office of Research Services, my supervisors or the Director of the School of Business (addresses and phone numbers are listed on the following page).
- * The participant's signature in no way constitutes a waiver of her/his rights. It is merely documentation that the subject was informed about what the research would entail, and, on this basis, agreed to participate.

I have understood the above information and agree to participate in this study.

Participant: Manager's name
Title
Name of company

Signature: _____

Researcher: Khalil N. Viraney

Signature: _____

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Carleton
UNIVERSITY

memorandum

OFFICE OF RESEARCH SERVICES
Faculty of Graduate Studies and Research
Duntun Tower, Room 1501
Tel. 788-2516, Fax 788-2521

DATE: April 18, 1995

TO: Professor V. Kumar (Supervisor), School of Business

FROM: Anne Burgess
Director of Research Services

RE: **Ethics Clearance**

I am writing to confirm that Khalil Viraney's research proposal ("Impact of Close Relationship on the Manufacturing Flexibility of the Firm") has been reviewed by the University Ethics Committee, and has been found to be ethically acceptable.

A.B.
MM

c.c. ✓ Khalil Viraney, School of Business

A SURVEY ON MANUFACTURER-SUPPLIER RELATIONSHIP

Please indicate whether,

a) you will be interested in receiving a summary of my study.

☐ Yes ☐ No

If yes, Company name _____

Tel # _____

b) you will be willing to clarify some points later should the occasion arise.

☐ Yes, your tel# _____ ☐ No
and name _____

I would like to divide your suppliers of raw materials and components into two groups.

- Group 1:** The parts/materials provided by these suppliers are:
 * standard or off-the-shelf items (e.g. screws, bolts, standard wires, resistors) perhaps used in many models
 or
 * consumables (e.g. stationary, office supplies) used through all the production cycles.
 The plant requires such parts/materials all the time and you design your products and operations keeping their specifications in mind. Your choice is limited by the variety offered by the suppliers. If you don't like them you choose a substitute from "catalogues."
- Group 2:** These parts are purchased on an as-needed basis. They are often custom-made only for you (e.g. special switches, printed circuit boards, custom built cables, integrated circuits, high resolution circuits, body components). This does not necessarily mean that you buy only one or few of them; but it does mean that you are able to influence their designs, material specifications, etc.

All the following questions concern the GROUP 2 suppliers

1. Approximately, how many Group 2 suppliers do you have?

2. With what percentage of these suppliers do you have a long-term (more than 2 years) implicit or explicit arrangement?

1	2	3	4	5
0%	1 - 15%	16 - 30%	31 - 50%	50% +

3. What percentage of total Group 2 parts purchased by your firm is obtained from only one or two sources?

1	2	3	4	5
0%	1 - 25%	26 - 50%	51 - 75%	75% +

4. Which of the following best characterize your relationship with your (Group 2) suppliers?

1	2	3	4	5
Exploitive	They mind their business; we mind ours	Warm to friendly	Mutual trust and dependence	They are treated as part of our company

The following questions assess the impact of

- * *information sharing*
 - * *involvement of suppliers in your firm's new product development efforts,*
 - * *supplier training programs, and*
 - * *your firm's efforts towards improving your supplier's quality and other capabilities*
- on YOUR FIRM'S MANUFACTURING CAPABILITY.

Although the questions appear *similar*, they refer to each of the above four dimensions separately. I would appreciate it if you could *isolate* the impact of each of the four dimensions on your different manufacturing capabilities.

INFORMATION SHARING

5. What percentage of Group 2 suppliers has access to your production schedule such that they can plan ahead in order to meet your requirements?

1	2	3	4	5
0%	1 - 25%	26 - 50%	51 - 75%	75% +

6. WHEN do you provide information regarding your schedule and subsequent changes in schedules to those suppliers who need to know?

1	2	3	4	5
Never or in extreme circumstances	On supplier's request	At regular intervals	Early enough for them to change their own schedule	Immediately upon making the changes

7. What percentage of the suppliers are on an EDI (Electronic Data Interchange) network with you?

1	2	3	4	5
0%	1 - 15%	16 - 30%	31 - 50%	50% +

8. To what extent do you make technical specifications (specs.) or designs available to your suppliers?

1	2	3	4	5
Only the necessary information for parts that the supplier makes for our firm	Detailed functional & engineering specs. for parts provided only when requested by the supplier	We always provide full functional & engineering specs. for parts that the supplier manufactures	Key product configuration information about where the parts are to be integrated is provided along with detailed specs. of the parts.	Complete product configuration information along with detailed specs. of the parts is always provided

9. To what extent do you exchange data about quality with your suppliers?

1	2	3	4	5
Never or only on supplier's request	Only if quality problems persist	Only at the start of a new part production and whenever there are quality problems	During annual or bi-annual meetings with suppliers	Regular exchange of quality control data

10. Consider information sharing about PRODUCTION SCHEDULE, TECHNICAL SPECIFICATIONS, NEW PRODUCTS and QUALITY CONTROL DATA.

In general, does information sharing about any or all of the above factors allow YOU to:

	Not at all	A little	Quite noticeably	Very much	A great deal	(✓) Difficult to say
a) produce a greater variety of products than BEFORE.	1	2	3	4	5	☐
b) switch production from one variety to another much faster than BEFORE.	1	2	3	4	5	☐
c) make greater number of major design changes in a product than BEFORE.	1	2	3	4	5	☐
d) produce a new product, or a product with major design changes much faster than BEFORE.	1	2	3	4	5	☐
e) make greater number of minor modifications to a product than BEFORE.	1	2	3	4	5	☐
f) implement minor modifications to a product much faster than BEFORE.	1	2	3	4	5	☐
g) respond to greater fluctuations in production volume than BEFORE.	1	2	3	4	5	☐
h) adjust the production level up or down much faster than BEFORE.	1	2	3	4	5	☐
i) make greater number of changes in scheduling than BEFORE.	1	2	3	4	5	☐
j) shorten delivery lead time	1	2	3	4	5	☐

SUPPLIER'S INVOLVEMENT IN PRODUCT DEVELOPMENT

11. To what extent do you involve some suppliers in the product design process?

1	2	3	4	5
Practically Never	Keep them informed	Occasionally consult with them	Allow opportunities for them to influence designs	Full participation from conception through design to manufacturing

12. Occasionally there may be a need to improve the performance of a product while it is in production. In such cases, do you consult your suppliers to tap their expertise?

1	2	3	4	5
Practically never	If suppliers offer their expertise	Only if required expertise is not available within the company	Expertise is sought in certain key areas even if we possess the expertise in those areas	Assistance is sought at every possible opportunity

13. In general, has suppliers' involvement in product design allowed YOU to:

	Not at all	A little	Quite noticeably	Very much	A great deal	(✓) Difficult to say
a) produce a greater variety of products than BEFORE.	1	2	3	4	5	☐
b) switch production from one variety to another much faster than BEFORE.	1	2	3	4	5	☐
c) make greater number of major design changes in a product than BEFORE.	1	2	3	4	5	☐
d) produce a new product, or a product with major design changes much faster than BEFORE.	1	2	3	4	5	☐
e) make greater number of minor modifications to a product than BEFORE.	1	2	3	4	5	☐
f) implement minor modifications to a product much faster than BEFORE.	1	2	3	4	5	☐
g) respond to greater fluctuations in production volume than BEFORE.	1	2	3	4	5	☐
h) adjust the production level up or down much faster than BEFORE.	1	2	3	4	5	☐
i) make greater number of changes in scheduling than BEFORE.	1	2	3	4	5	☐
j) shorten delivery lead time	1	2	3	4	5	☐

SUPPLIER TRAINING

14. Do you offer any training programs to your suppliers to improve their capabilities in areas such as quality, manufacturing processes, packaging and transportation methods?

☐ Formal training ☐ Informal training ☐ Both ☐ None

Please describe briefly

Formal:

Informal:

15. When did you first introduce training programs for your suppliers?

16. How many suppliers have participated in your training programs, formal or informal?

17. In general, to what extent has your training approach improved the SUPPLIER'S:

	Not at all	A little	Quite noticeably	Very much	A great deal	(✓) Difficult to say
a) ability to produce better quality parts/ components	1	2	3	4	5	☐
b) setup time	1	2	3	4	5	☐
c) productivity	1	2	3	4	5	☐
d) manufacturing process capability	1	2	3	4	5	☐
e) delivery time	1	2	3	4	5	☐

18. How has your effort to train suppliers benefited YOUR firm?

QUALITY IMPROVEMENT PROGRAMS

19. Under what circumstances do you offer assistance to your suppliers for SOLVING their quality problems?

1	2	3	4	5
Never (it is their responsibility)	When the problem starts significantly affecting our own quality	When they inform us of any quality problems	When they experience some difficulty in solving the problem	As we come to know about their quality problems - no matter how small

20. In what area(s) do you help your suppliers improve? and, how do you help them?

METHODS OF HELP

Capabilities	Through formal training programs or special courses (✓)	By arranging meetings, conferences (✓)	By offering expertise as needed (✓)	Total # or % of suppliers helped
Production Scheduling				
Planning Process				
Quality				
Product Design				
Packaging				
Transportation				
Other (please specify)				

21. In general, has helping suppliers improve their capabilities allowed YOU to:

	Not at all	A little	Quite noticeably	Very much	A great deal	(✓) Difficult to say
a) produce a greater variety of products than BEFORE.	1	2	3	4	5	☐
b) switch production from one variety to another much faster than BEFORE.	1	2	3	4	5	☐
c) make greater number of major design changes in a product than BEFORE.	1	2	3	4	5	☐
d) produce a new product, or a product with major design changes much faster than BEFORE.	1	2	3	4	5	☐
e) make greater number of minor modifications to a product than BEFORE.	1	2	3	4	5	☐
f) implement minor modifications to a product much faster than BEFORE.	1	2	3	4	5	☐
g) respond to greater fluctuations in production volume than BEFORE.	1	2	3	4	5	☐
h) adjust the production level up or down much faster than BEFORE.	1	2	3	4	5	☐
i) make greater number of changes in scheduling than BEFORE.	1	2	3	4	5	☐
j) shorten delivery lead time	1	2	3	4	5	☐

22. Up to this point we have discussed information sharing, joint product development, supplier training programs and quality improvement efforts. In your opinion which of the above factors have contributed most towards developing a better relationship with your suppliers? Are there any additional factors that have helped improve your firm's relationship with its suppliers?

23. Do you experience variations in the quality of material that you receive from your suppliers?

☐ Yes ☐ No

24. To what extent do any of the following activities relate to noticeable improvement in the quality of material that you receive from your suppliers?

	Not at all	A little	Quite noticeably	Very much	A great deal	(✓) Difficult to say
a) <i>Exchanging information regarding technical specifications and quality control with your suppliers.</i>	1	2	3	4	5	☐
b) <i>Involving suppliers in new product design.</i>	1	2	3	4	5	☐
c) <i>Training Suppliers</i>	1	2	3	4	5	☐
d) <i>Helping suppliers improve quality and other capabilities.</i>	1	2	3	4	5	☐

25. Do you use any formal mechanism to recognize your suppliers' contribution to your firm's operation?

☐ Yes ☐ No

If yes, please explain:

PERSONAL DETAILS (Please note that the following information will be treated as *strictly confidential* and will be used for statistical analysis only)

Position: _____

Number of years with the company: _____

THANK YOU FOR YOUR HELP

APPENDIX C

Additional views of 10 Companies are presented in this appendix.

Company 1:

The manager of this firm stated that all contracts with suppliers were long-term and that the company firmly believed in single sourcing. Suppliers were always asked to hedge (make arrangements) for 30% additional demand in case of need. In case the supplier cannot manage to supply the additional request, it is often asked to make alternate arrangements and procure the required material from other plants. The manager considered sharing production schedules with suppliers as being extremely important.

He also said that his firm provides specialized equipment and extra tooling to its suppliers so that they can produce the specialized parts for them according to specifications. This assistance also serves to assure that suppliers do not have an excuse to deliver poor quality.

The company has regular meetings during which the suppliers are asked to give suggestions. In case the suggestions clash, suppliers are asked to 'sit down and sort it out', either with the company or other suppliers. In case of a dispute between suppliers, the manager's firm offers whatever help it can to resolve the dispute.

The manager also claimed that suppliers provide valuable suggestions regarding cost reduction. The benefits of such reductions, up to a certain limit, are transferred to

suppliers; benefits beyond this limit are shared by both the firm and its suppliers. Thus, we can see that this firm has developed a good relationship with suppliers, continuing to help and encourage them.

Company 2:

One of the large companies interviewed does not provide free training to its suppliers. However, it does have training programs which any company can join. In other words, the company trains its suppliers but charges them for it. Suppliers can join such training programs elsewhere if they wish to do so. The manager did not offer any reasons for such a policy.

Company 3:

The manager of this firm had a different perspective on M-S relationship. He indicated that his Group 2 suppliers contributed to only 10% of the product. This company produces a unique, large and expensive product, with an annual volume of under thirty. As a result, the company does not require mix or changeover flexibility. The manager interviewed stated that the same product has been manufactured by the firm with minor modifications for the past 20-30 years.

Based on these interesting views, it was decided to conduct a supplementary analysis in order to determine whether this particular firm was having a significant effect on the overall results, especially on mix, changeover and volume flexibility. However, analysis indicated that the firm in question had no significant effect.

The strategy of this company is to manufacture every component in-house. Only when there is a shortage of capacity or lack of expertise/capability does there arise a need for subcontracting. In other words, the company discourages the development of a close relationship with suppliers. One of the policies of the company includes no long-term contracts with suppliers. Furthermore, for every new requirement, the company searches for suppliers which can provide the specialized parts.

The management's strategy is to compete on delivery and not on cost. The company believes that suppliers tend to delay and the best strategy for meeting on-time delivery is to try to manufacture all requirements in-house. As a result, the company does not wish to depend on suppliers.

Company 4:

The manager of this firm employs the 8-Discipline program similar to that instituted by Ford. This program is aimed at improving various capabilities of suppliers, such as quality, delivery and manufacturing processes. Most of the company's suppliers belong to the Group 2 category and are suppliers of highly specialized equipment.

An interesting remark made by the manager was that vertical integration is inversely related to developing close relationship with suppliers. This remark is corroborated by that of the manager of Company 3, where its efforts to manufacture everything in-house have been detrimental to developing a better relationship with suppliers.

Company 5:

The manager of this company claimed that involving suppliers has significantly helped the company. He cited an example in which a small design specification of the manufacturer added 10% to the material costs of the supplier. After consultations, the supplier was given the freedom to manufacture the component, following which the company did not have any problems. The component met the quality expectations of the manager and the cost savings realized were shared equally between both parties. Thus, the supplier's expertise benefitted both parties involved. In fact, the manager confirmed that many of his suppliers are already in the company's premises, offering their expertise.

The manager admitted that before involving suppliers, the company maintained a high inventory of \$14 million to support annual sales of \$44 million. Currently, the company has an inventory of \$4.6 million for sales of \$57 million. Thus, we can see that one of the primary motivations for developing a close relationship with suppliers is cost benefits. If a firm realizes that suppliers can contribute towards cost reduction, it will always try to establish closer ties with suppliers.

Company 6:

Managers of this company claimed total involvement of their suppliers in their company's operations. Suppliers have full access to the company's production schedule. By being on-line, the suppliers can even make changes in the company's production schedule. The company has not established an EDI network with suppliers but plans to

do it in the next six months.

Suppliers are trained in every aspect of production. The entire training program is on-line for suppliers so as to enable them to train their respective suppliers. This company offers expertise to even its suppliers' suppliers.

Suppliers are allowed more freedom in manufacturing parts and components. Some of the tolerance levels specified by the company's engineers are geared more towards meeting company policy rather than product quality. Suppliers are sometimes forced to expend great effort in terms of raw materials, labour or costs in order to meet such tolerance levels. In such cases, suppliers have been given the freedom to change the tolerance levels as long as this does not affect quality.

For many standardized and custom made parts, suppliers are in-house and the company's engineers have the freedom to go directly and place an order with the suppliers. The company works with its suppliers to reduce the Total Cost of Procurement (TCOP) and extensively consults them on how such costs can be reduced. Moreover, the company freely discusses the issue of profits with its suppliers. The company believes that, "everybody is here to make money, so let's discuss how each of us can make more money".

Suppliers which perform well receive a larger share of the contracts. According to the managers, time to market is one of the most important competitive factors. The company realizes that suppliers can offer significant help in achieving this objective.

Company 7:

This company's views were very similar to Company 3. As with Company 3, this company deals in highly-sophisticated specialized equipment with a low production volume. The company mainly bids on government contracts and the government frequently provides the company with a list of vendors. As a result, the list changes with every new contract and the company generally uses the vendor list to buy from the cheapest source. Such a policy is not conducive to developing a better relationship with suppliers.

Since this company was also not interested in achieving mix and volume flexibility, an analysis was performed, excluding this company, along with Company 3, in order to determine whether these two companies are significantly influencing the results. However, no significant effect of these two firms on the overall results was found.

Company 8:

The managers of this company acknowledged that they did not have good communication with their suppliers and realized the need to improve relationship with suppliers. The interview was an eye opener for them.

Company 9:

This company was operating in a job shop environment. The design of its products have evolved over a period of twenty years, not needing major design changes except for

minor modifications. As a result, this company was not involved in any joint product development activities with suppliers. However, it had a reasonably good relationship with suppliers, offering them any assistance and using their expertise whenever required.

Company 10:

This company makes unique designs with a small production volume. The company has developed good relations with suppliers in certain areas but does not feel the need to develop relations any further. For example, the managers expressed discomfort at the fact that they could not show suppliers why a certain part, provided by the suppliers, was not functioning because it was difficult to transport the suppliers to the installation site. On further probing, it was revealed that, in certain cases, the manufacturers have in fact transported suppliers to the installation site. In one case, the supplier's suggestion was extremely useful and the problem was easily resolved. Thus, this company seems to have not realized the full potential of involving suppliers.

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