A STRATEGIC MANUFACTURING
PLANNING DECISION
SUPPORT SYSTEM

By

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CHAPTER I

INTRODUCTION

In the United States, the gross national product is comprised of service industries (63%), manufacturing (24%), and the extractive (e.g., agriculture) and construction industries (13%) (Teicholz, 1985). Since "service" does not result in the "direct" creation of wealth, then it follows that manufacturing is responsible for close to two thirds of the United States' real wealth. Obviously, any tool that increases manufacturing productivity will have a profound effect on the GNP. At the present time, technology, particularly Computer Integrated Manufacturing (CIM), appears to hold the greatest potential for improving manufacturing productivity.

According to (Buffa, 1985), the problem in many countries is that managers have had their attention captured by marketing in the 1960's and finance in the 1970's and 80's and they have forgotten the basic requirements of manufacturing: produce something of value, at a low cost, of high quality, and make it available when it is demanded. "Manufacturing strategy was not taken into account in company strategy formulation."

Of all the things that can change the rules of competition, technological change is among the most prominent. There is, therefore an urgent need for the incorporation of engineering design and manufacturing into strategic planning.

Little attention has been paid to the establishment of a systematic engineering design and manufacturing strategy. The major emphasis of this research is the development of the structure of a strategic manufacturing planning decision support system. The basis of the system is provided by the development of a conceptual methodology for accomplishing strategic planning for engineering design and manufacturing.

The methodology is a combination of the adaptation of selected existing methodologies and the research effort. With the growing complexities and diversity of operations with which companies will have to deal in the future, it is important to achieve manufacturing strategic planning. Recent worldwide economic and market competitive forces have influenced the consideration of design and manufacturing as vital elements in the identification of business strategies.

The proposed research deals with the upper level of the Computer Integrated Manufacturing - Simulation Model (CIM-SIM) framework being developed at the Center for Computer Integrated Manufacturing in the School of Industrial Engineering and Management at O.S.U. The contribution and boundaries of this research to the CIM-SIM project are represented in Figure 1.1 by dashed lines.

The research topic was chosen mainly because of a continuous personal interest in strategic planning and in computer integrated manufacturing.

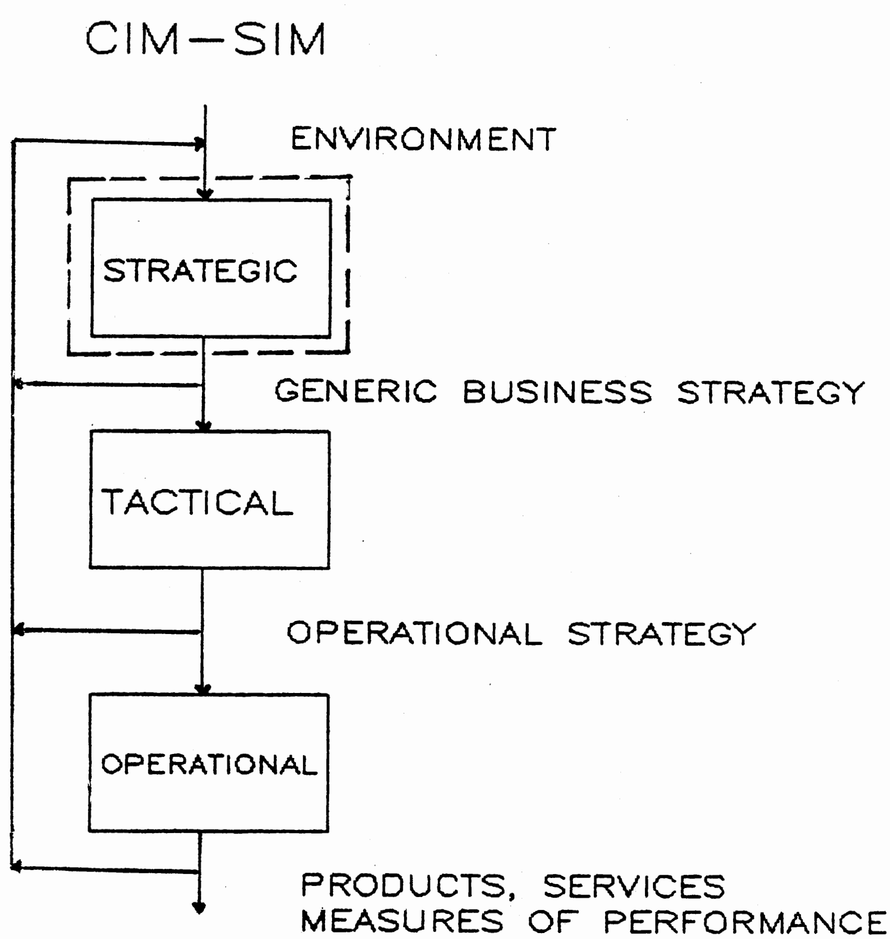

Figure 1.1. CIM-SIM Planning Levels

CHAPTER II

STATEMENT OF THE PROBLEM

It is becoming evident that new manufacturing technologies are revolutionizing manufacturing worldwide. Related to this phenomenon, the increasingly automatic factories of the future will result in a new systems orientation to strategic management and will, at last, make production a part of the top management team. Technological changes currently underway will change not only how industry makes goods, but also the way in which management thinks about the role of manufacturing. Manufacturing will become increasingly total-systems based, which "promises a revolution the likes of which business has not seen since the introduction of mechanized power in the eighteenth century" (Thompson and Paris, 1982).

The manufacturing world is being swept by broad, pervasive changes. The pace of change has become almost overwhelming. Competitive pressures will require many companies to reduce their product prices by a large percent per year while simultaneously increasing quality dramatically and improving responsiveness to their customers. Many companies will find it more and more difficult to remain competitive in the world market (Mize, 1986a).

With competitiveness as the imperative, the central focus should be on defining manufacturing strategy and developing it in the context of the overall company strategy. All the activities in the line of material flow, from suppliers through fabrication and assembly and culminating in product distribution, must be integrated into a sensible manufacturing strategy.

There is a need to address the following problems and issues:

First, there is a need for a manufacturing strategy that firmly supports that company's business strategy. Example: We continue to find that a high quality product is an essential part of the business strategy, but the company's plant manager is paid on the volume of product that goes out the door.

Harrington (1984) argues that, what will separate winners from losers is a process that will transfer these vague manufacturing strategies into an implementable action plan that achieves concrete measurable results against standards established by the competitive business world.

There is a need therefore for the incorporation of Computer Integrated Manufacturing (CIM) into a firm's strategic business plans in order to gain competitive advantage.

With respect to the use of the computer and information/ communication technologies, one of the problems in talking about CIM is that it seems to be all things to all people.

Perhaps this is not surprising since we should expect our concept of CIM to evolve as more technological integrating advances are made. However, the following CIM definition (Mize, 1985) adopted by major firms is considered for the purpose of this study:

> "CIM is the use of the computer and information/ communication technologies to effectively integrate all of the
>
> o engineering / design functions,
> o manufacturing planning functions,
> o equipment / process technologies,
> o manufacturing control processes, and
> o management functions
>
> necessary to convert
>
> o raw materials,
> o labor,
> o energy, and
> o information
>
> into a high quality, profitable product, within a reasonable amount of time."

Although CIM technologies are not a strategy in themselves, they are among the most powerful tools available for implementing various competitive strategies. In the hands of a competitor, CIM tools become a threat, while managed competently within an enterprise, they represent a competitive opportunity.

Second, factory automation often focuses on technical features instead of the proven strategic benefits that such factory automation can deliver. Because most CEOs and board members come from financial, legal or marketing backgrounds, they often lack knowledge and a true understanding of design and manufacturing as it was ten years ago, as it is today, and, more important, as it will have to be in the next five to ten years.

<u>Third</u>, with traditional capital budgeting techniques, it is difficult to justify investing in risky long term factory automation programs. There is no base of experience to deal with factoring benefits other than direct labor reduction or increased capacity into the justification calculations. Then, too, most top executives seldom adopt a truly corporate-wide outlook for planning their design and manufacturing strategy and capital improvements to increase their strategic effectiveness as well as efficiency/ productivity.

<u>Fourth</u>, many executives simply don't have an objective picture of where their company currently stands with respect to the competition, that is, the ability to execute its design and manufacturing mission effectively. <u>They also lack knowledge of their competitors' design and manufacturing capability</u>. Thus, they have difficulty planning or implementing change because they lack any frame of reference about their current position <u>vis a vis</u> their competitors or the state of the art in their industry, in addition to what they will have to accomplish to be competitive as a manufacturer for world markets in the future.

There are some reasons why company management should approach CIM from a strategic perspective. The first is that CIM is likely to represent a significant investment whether or not it is treated as a significant strategic issue. The second reason is that many CIM investments will fail to provide any real strategic advantages (Marks, 1984).

Each firm's competitive fate would rest heavily on the ability to create facilities that generate performance advantages - and do it faster than competition (Ramchandran, 1986). The ability to compete in world markets with a well-defined design and manufacturing strategy is more than ever the essence of business today.

A sound methodology for accomplishing and evaluating engineering design and manufacturing strategic planning is needed as a fundamental prerequisite to address these problems. This research provides the basis of such methodology considering the four issues mentioned before, and it is formalized in a strategic manufacturing planning decision support system.

CHAPTER III

BACKGROUND OF THE STUDY

This chapter presents a summary of the review of the literature search. In conducting the search, it was discovered that there was no substantive body of readings on the specific subject of strategic planning for engineering design and manufacturing. Most of the literature reviewed was concerned with general theory of strategic planning and general guidelines of its application to different functional areas. However, they provided the basis for this research and therefore it is important to present them in this chapter.

3.1 Design / Manufacturing Technologies

3.1.1 Introduction

Manufacturing is evolving from an art or a trade into an important science. A quarter of the population is involved in some form of manufacturing activity, and the rest of the population benefits from the products. When manufacturing was still an art, or rather a collection of very different arts, each had its own unique technology. We now see manufacturing as a science whose fundamentals are independent of what is being made, or when it is being made. It has a structure that is the key to understanding the science, and understanding is the key to the profitable application of the science. Most important, this structure is invariant, so that once understood, the knowledge may be applied to any of the many technologies, (Harrington, 1984).

3.1.2 Definition

Manufacturing is the conversion of naturally occurring raw materials and synthetic materials into desired end-products. The word derives from two Latin word roots meaning "hand" and "made" - almost literally "handmaking". In early civilizations, products were indeed hand made; human muscle power and mental control moved crude tools over materials gathered by hand. Today, few products are made by human, or even animal muscle power. Other sources furnish the power, but humans still conceive the products and guide the operations of production.

In the broadest sense, manufacturing begins with the acquisition of raw materials, and extends throughout the whole gamut of activities of production to the distribution and, if necessary, the maintenance of the end-products.

The word "manufacturing", in this field is as diverse as the segments of the field, if not more so. Individual companies in a single segment may give the same word quite different meanings. The word manufacturing itself is a good example: in some instances it refers to everything the company does; in others it refers to everything except marketing; in still others it refers only to the fabrication and assembly departments and excludes product design as well as marketing.

In this proposal, manufacturing will encompass the entire range of activities from product concept to maintenance of past products in the field, and everything in between. It will include product conception, product design, manufacturing engineering, fabrication of parts, assembly, test, distribution, and support. It will include all the managerial functions necessary to integrate and operate the activity reliably, profitably, and in a timely manner.

Harrington, 1984, considered those elements of discrete parts manufacturing potentially susceptible to computer control to be the following:

- o Designing the product
- o Engineering the manufacturing process
- o Deciding how many and when to manufacture
- o Scheduling the steps in the process
- o Controlling the tools and energy used
- o Monitoring the execution
- o Collecting and processing data on accomplishment.

This view excluded many other management functions involved in manufacturing such as:

- o Exercise of creativity in marketing, product conception, or manufacturing methods
- o Selection, hiring, and firing of personnel
- o Training, supervision, and discipline of personnel

- o Relations between management, workers, vendors, and the public
- o Procurement and control of funds involved in the manufacturing operation
- o Attention to legal affairs involved in operating a concern
- o Selection of objectives and broad policy problems.

All of these functions will be affected by computer integrated manufacturing, but the link will be through humans rather than through the computers.

Harrington, 1973, divides manufacturing into two sequences, one of which could be called the design cycle, and the other, the material cycle. The design cycle refers to the events occurring in the development of a specific product design, while the material cycle refers to the events occurring in the production of an individual piece of material taken from raw stock through to finished article.

Technology usually implies a "practical application of scientific or engineering knowledge." Thus, conceptually, technologies lie between the scientific and engineering disciplines and the products that the companies sell or use. To be a useful concept for analysis, a technology should fit the form:

We know how to ________ (verb) ________(noun). (Lamb, 1984)

Example: We know how to formulate PVC resins.

By defining technologies in this way, we can relate them to products and processes, assess their relative technical strength against that of the competition, and evaluate them in many ways. For example, we can "unbundle" a product or process into its discrete technologies and identify the resources to practice these technologies. The application of technologies as a system to develop successful products or processes is also regarded as a technology. This is unique to the products or processes, and we call it a "systems technology."

Important elements in a technological analytical framework include:

- o A precise and useful definition of technology
- o The strategic role of technology
- o The linkage of technological strategies to business strategy
- o The changing nature of technologies
- o The international factors in the deployment of technology
- o The process of technological planning

These concepts are explained in more depth in the remainder of this chapter and the following chapter.

From Peter Drucker's book, "Technology Management and Society" (1977), technology is, quite simply, know-how. In most cases, it is scientific know-how embodied in people, plants, patents, laboratories and equipment. This know-how results in a manufacturing process or product, or a service (or all of these) that, if recognized as a resource, can be managed. When properly managed, technology complements business strategy in mature companies, drives business strategy in high-technology companies and, in most industries, can be leveraged to achieve a sustainable, competitive advantage in the marketplace. The key lies in formulating the right technology strategy and, ultimately, integrating it into the corporate planning process.

3.1.3 Manufacturing Strategy Decisions Categories

Because of the diversity of manufacturing decisions that must be made over time, an organizing framework that groups them into categories is useful both in identifying and in planning a firm's manufacturing strategy. A framework that Hayes and Wheelwright, 1984, have found particularly helpful in working with a variety of firms uses eight major categories, as summarized in Table 3.1.

It is the collective pattern of these decisions that determines the strategic capabilities of a manufacturing organization.

The first four decision categories in Table 3.1 are typically viewed as "**structural**" in nature because of their long-term impact, the difficulty of reversing or undoing them once they are in place, and the fact that a substantial capital investment is required to alter or extend them. The last four decision categories generally are considered more "tactical" in nature because they encompass a myriad of ongoing decisions, they are linked with specific operating aspects of the business, and they generally do not require highly visible capital investments.

TABLE 3.1

MANUFACTURING STRATEGY
DECISION CATEGORIES

Capacity - amount, timing, type
Facilities - size, location, specialization
Technology - equipment, automation, linkages
Vertical Integration - direction, extent, balance
Workforce - skill level, wage policies, employment security
Quality - defect prevention, monitoring, intervention
Production planning/materials control - sourcing policies, centralization, decision rules
Organization - structure, control/reward systems, role of staff groups

(Hayes and Wheelwright, 1984, p. 31)

Some of the important subareas within each of these categories are also listed in Table 3.1. For example, the technology category includes decisions regarding the technology that is incorporated in specific pieces of manufacturing equipment, the degree of automation in the production and material-handling processes, and the connections between different production stages. These eight decision categories are closely interrelated.

Over time, management must make decisions in all these categories, each of which presents a variety of choices and can have a major impact on the manufacturing function's ability to implement and support the organization's business strategy.

It is this pattern of structural and intrastructural decisions that constitutes the "manufacturing strategy" of a business unit. More formally, a manufacturing strategy consists of a sequence of decisions that, over time, enables a business unit to achieve a desired manufacturing structure, infrastructure, and a set of specific capabilities.

Defining manufacturing strategy in terms of a pattern of decisions suggests criteria for evaluating the appropriateness of a given manufacturing strategy. These criteria generally fall into one of two groups, as indicated in Table 3.2. The first group concerns various types of consistency: one manufacturing strategy is considered "better" than another to the degree that it displays more internal consistency (within the manufacturing function and across functions in the business unit) and/or external consistency (between the manufacturing function and the environment of the business unit). The other group of criteria concerns the degree to which the manufacturing strategy augments the external competitiveness of the business, that is, enhances the competitive advantage it is seeking.

TABLE 3.2

CRITERIA FOR EVALUATING A MANUFACTURING STRATEGY

Consistency (internal and external)

Between the manufacturing strategy and the overall business strategy
Between the manufacturing strategy and the other functional strategies within the business
Among the decision categories that make up the manufacturing strategy
Between the manufacturing strategy and the business environment (resources available, competitive behavior, governmental restraints, etc.)

Contribution (to competitive advantage)

Making tradeoffs explicit, enabling manufacturing to set priorities that enhance the competitive advantage
Directing attention to opportunities that complement the business strategy
Promoting clarity regarding the manufacturing strategy throughout the business unit so its potential can be fully realized
Providing the manufacturing capabilities that will be required by the business in the future

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(Taken from Hayes and Wheelwright, 1984, p. 33)

3.2 Strategy and Structure Literature Review and Its Application to Engineering Design and Manufacturing.

3.2.1 Introduction

The growth and survival of an organization depends on certain key strategies. The earliest work in this area identified the strategies of volume, geographic dispersion, vertical integration and product diversification as key strategies (Chandler, 1962). The volume strategy relates to an increase in the quantity of goods produced. Geographic dispersion indicates that the goods are sold in a wider area than previously. Vertical integration refers to changes in the scope of the business; backward integration is concerned with expansion in the direction of supply (the input side) while forward integration implies expansion toward the market (the output side). Very often companies come into being with a single product but over time product diversification is mandated both to broaden the range of products and to introduce improved products.

Chandler showed that each strategy gave a different type of difficulty which was addressable by a different form of organizational structure. This initial study has led to much research on the role of strategy and structure on the growth of the firm. The concept of "fit" has been introduced to describe how well the structure of the company matches the adopted strategy. The implication is that companies with a good fit, in other words with a consistent strategy and structure, prosper compared to those companies with a mix-match or non-optimal fit. However, an adopted strategy does not exist in isolation, but is influenced by the environment in which the organization exists. Environmental factors such as rate of change in technology, competitive pressures, economic forces and many others greatly influence the success of a chosen strategy and therefore must modify or entirely determine the choice of strategy.

3.2.2 Strategy and Structure

According to Hofer and Schendel, strategy is the set of basic characteristics of the match an organization achieves with its environment (Hofer and Schendel, 1978). Strategy is a means for coping with both external and internal changes. Strategy is the path charted for the organization and is linked to the organizational goals and objectives which are to be achieved. Hofer and Schendel go on to discuss the different definitions of strategy which have been given in the literature (Hofer and Schendel, 1978). It is pointed out that some authors do not differentiate between strategy as a concept and the formulation process itself. In addition there is major disagreement over whether strategy is a broad or a narrow concept. The broad concept of strategy includes not only the ends, the goals and objectives, but also the means used to achieve these ends. The narrow view of strategy is that it is a description of the means employed to achieve goals and objectives set in a separate process. Hofer and Schendel choose the narrow concept and consider goal setting and strategy formulation as two distinct, but interrelated processes. This narrow definition of strategy is recommended here.

Some important characteristics are common to the use of the term strategy in business. (Hayes and Wheelwright, 1984):

1. <u>Time horizon</u>. Generally, the word strategy is used to describe activities that involve an extended time horizon, both with regard to the time it takes to carry

out such activities and the time it takes to observe their impact.

2. Impact. Although the consequences of pursuing a given strategy may not become apparent for a long time, its eventual impact will be significant.

3. Concentration of effort. An effective strategy usually requires concentrating one's activity, effort, or attention on a fairly narrow range of pursuits. Focusing on these chosen activities implicitly reduces the resources available for other activities.

4. Pattern of decisions. Although some companies need to make only a few major decisions in order to implement their chosen strategy, most strategies require that a series of certain types of decision be made over time. These decisions must be supportive of one another, in that they follow a consistent pattern.

5. Pervasiveness. A strategy embraces a wide spectrum of activities ranging from resource allocation processes to day-to-day operations. In addition, the need for consistency over time in these activities requires that all levels of an organization act, almost instinctively, in ways that reinforce the strategy.

Because the word strategy is used in a variety of settings and has such a range of definitions, it is useful to identify and contrast different types of management-related strategies. As outlined in Figure 3.1, business organizations, especially those structured around functionally organized business units, develop and pursue strategies at three levels. At the highest level, corporate strategy specifies two areas of overall interest to the corporation: the definition of the businesses in which the corporation will participate (and, by omission, those in which it will not participate), and the acquisition and allocation of key corporate resources to each of those businesses (Hax, 1984).

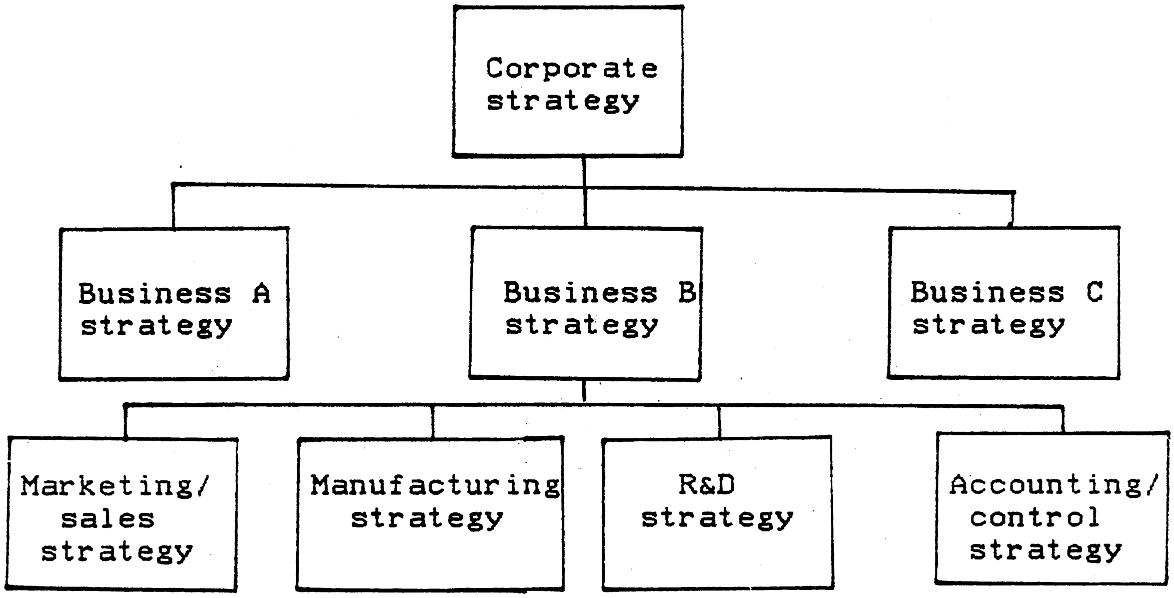


Figure 3.1. Levels of Strategy

The second major level of strategy identified in Figure 3.1 is that associated with a strategic business or planning unit (SBU or SPU), which is usually a subsidiary, division or product line within the firm.

A business strategy specifies (1) the scope of that business, in a way that links the strategy of the business to that of the corporation as a whole, and (2) the basis on which that business unit will achieve and maintain a competitive advantage. Specifying the scope of a business requires a statement of the product/market/service subsegments to be addressed.

A given SBU might achieve a defensible competitive advantage using one of a variety of approaches, including such generic ones as "low cost/high volume," "product innovation and unique features," or "customized service in selected niches." To be effective, such an advantage must be sustainable using the unit's own resources, take into account competitors' strategies, and fit the customer segments being pursued, (Porter, 1985).

The third level is comprised of functional strategies. Once a business unit has developed its business strategy, each functional area must develop strategies that support this strategy. To be effective, each functional strategy must support, through a specific and consistent pattern of decisions, the competitive advantage being sought by the business strategy.

A historical perspective on planning is included in Figure 3.2 to identify the point in time of when the strategic issues evolved in planning.

Figure 3.2 presents a historical perspective on planning.

ACTIVE TIME PERIOD		FOCUS	CONTENT
1956 - 68 on	Functional Planning	. Emphasis on plans by function . George Steiner, Top Management Planning	$ budget items
1964 - 68 on	Bottom-up Planning	. Emphasis on plans being created by the lowest level organizational units . Stanford Research Institute, The Corporate Development Plan	$ Expense & Capital items
1968 on	Top-Down Planning	. Senior Management specifies precise direction, organization fills in the details . Wilson, S.R. and Toombs, J.O., Improving Profits Through Integrated Planning and Control	$ Expense, Capital & non-dollar items
1970 on	Top-Down Guidance, Bottom-up Planning	. Emphasis on iteration between levels in the organization and the focus on the situational context . Vancil and Lorange, Strategic Planning Systems	Heavy emphasis on process
1973 on	Strategic Content	. Emphasis on key analytical concepts . Henderson, On Corporate Strategy	Experience Curve, market position & lifecycle
1979 on	Integrated Strategy	. Stresses financial market expectations; strategic content; industrial economics planning process; strategic program implementation	Includes much of the above together with Finance (CAMP) and Economics (I.O.)

Figure 3.2. A Historical Perspective on Planning (Taken from Morton, MIT 1981, p. 103)

Since there exists a hierarchy of strategies, there must also exist a hierarchy of goals (Richards, 1978). If goals are the ends and strategies the means, there exists a means-ends chain. The first step is to set the goals for the highest level and this then defines the strategies to be employed; an iterative process is used between the goals and strategies until a consistency is reached.

Organizations are purposeful social units which consist of people who carry out differentiated tasks which are coordinated to contribute to the goals of the organization (Dessler, 1976). Structure has been defined as "those aspects of behavior and organizations subject to existing programs and controls" (Lawrence and Lorsch, 1967). Structure in an organization thus refers to information flow and to the hierarchy of decision making. For further detail, excellent examples of different structures are given by Dessler, 1977. Factors to be taken into account in the design of an organizational structure include centralization or decentralization, line and staff function, organization by product or by geographical area, and many others. There are many different arrangements of company units which can be adopted. Contingency theory would state that there is no one best way of organization but that the structure should reflect the strategy.

3.2.3 The Environment

A considerable amount of study has been undertaken to define the environment of the firm. Duncan has summarized the studies on the environment up to 1973 and found that there are two dimensions to the environment, simple-complex and static-dynamic (Duncan, 1972). Prior to that report, an uncertainty scale was constructed to measure environmental uncertainty (Lawrence and Lorsch, 1969).

The above studies on the environment have examined measures which are related to the tasks of the organization. This so-called task environment is the one which immediately influences the organization. However there is a broader environment which will include socioeconomic, political and technological factors which may only influence the organization in the long run, (Hrebiniak and Joyce, 1985). The boundary between the organization and the environment is not sharp. Thus the organization spills over into the environment and the environment intrudes into the organization (Galbraith, 1979). All these factors complicate the definition of organization and environment.

3.2.4 The Influence of Technology

The studies on strategy and structure have not explicitly focused on the role of technology (Product/Process) and on R & D. At this time, the role of technology in corporate strategy will be addressed.

Ansoff has considered the situation of technology in the diversification of a company's products (Ansoff, 1965). The first step is to examine the product/mission matrix of the organization.

A product/mission matrix

Mission	Product: Present	Product: New
Present	Market penetration	Product development
New	Market development	Diversification

At the business level, Ansoff and Stewart have discussed strategy and technology (Ansoff and Stewart, 1967). In technically intensive businesses, the marketing strategy involves a technological component. Four strategies were identified. In the "first to market", strong R & D, technical leadership and risk taking are required. The "follow the leader" strategy is based on strong development resources and an ability to react quickly as the market starts its growth phase. "Application engineering" is based on product modifications to fit the needs of particular customers in a mature market. "Me-too" strategy is based on superior manufacturing efficiency and cost control.

Ansoff and Steward also pointed out that technological change can exert a major influence on the nature of effective competitive strategies in particular industries. The two aspects of technological change that are important are the overall rate of change and the variations that occur at different stages of the product market evolution (Hofer and Schendel, 1978). Hofer and Schendel have related the rate of technological change in a field to the type of variation that could occur in the cases of product design, process design and breakthrough. This is shown in Table 3.3. For example, in industries with high rates of technological change the major challenge will involve the types of design change and the time needed to mass produce a design once the design has been frozen. Major breakthroughs in product form will be the principal type of technological threat to firms in industries with low overall rates of technological change.

TABLE 3.3

HYPOTHESIZED VARIATIONS IN THE MAJOR TYPES OF TECHNOLOGICAL CHALLENGES PARTICULAR BUSINESSES WILL FACE

		Type of technological change		
		Product design	Process design	Breakthrough
Overall rate of technological change	High	Major	Intermediate	Moderate
	Medium	Moderate	Major	Intermediate
	Low	None	Moderate	Major

(Taken from Hofer and Schendel, 1978, p. 137)

The major challenge facing firms in industries with intermediate rates of technological change is the problem of changing from a product to a process focus in the engineering and R & D activities.

The approach of Ansoff has been extended by Abell (Abell, 1980). Whereas, Ansoff defines the business in terms of a product/market mission, Abell adds an extra dimension to define the business along three coordinate axes labelled customer groups, customer functions and alternative technologies. Thus the present business can be defined in three-dimensional space. This analysis will indicate obvious gaps that can be filled. For example plotting the present position could indicate that with the existing technology and functional use, another group of customers could be served. The possibilities for diversification are indicated quite graphically. Often in diversification attempts, companies move far away from the known product/market relationships of the existing business. The definition of the present business along the three dimensions will give a three-dimensional picture which indicates the relative distance from the existing business and hence gives an idea of the risk and of the opportunities. The existence of a customer/function/ technology domain can be used to analyze distinctive competence which is another indicator of where the business should go next.

The concept of maturity is particularly useful in arranging the technological portfolio of a corporation.

Questions, generally concerned with the business opportunities and threats presented by the technological resources of the corporation, can be addressed by the following steps:

- o Identify the technologies relevant to the industry
- o Assess their maturity and the impact on products and processes
- o Estimate the competitive strength of the corporation in each technology.

Companies must be able to identify the technology of the moment - which, Lamb 1984, calls the "key" technology - but must also recognize the threat of other technologies that may replace the "key" technology. Lamb calls these "pacing" technologies.

1. The "pacing" technology has the potential to overturn the existing competitive structure.

2. The better-positioned competitors are generally those strongest in this "key" technology as long as they are positioned well in the other factors making up the basis of competition.

3. While it is necessary, simply being proficient in the "base" technology is not enough - this does not provide competitive differentiation.

Furthermore, because competitive dynamics depend so heavily on industry maturity, it is critical to recognize the difference between technology and industry maturities and their influence on the nature of competition.

3.2.5 Life Cycle Concepts

The concept of the product life cycle was introduced some 30 years ago, but it is only rather recently that the concept has been broadened to include the idea that a firm which stays in the same business also has a finite lifespan. Strategies at the corporate, business and functional levels are enriched by consideration of the lifetime concept.

3.2.5.1 Product, Process, Company, Industry. Seven stages of product/market evolution are identified. These are market development, growth, shake-out, maturity, saturation, decline and petrification. The basic nature of competition changes during the development, shake-out and decline stages of product/market evolution and major changes in competitive position are accomplished most easily during these stages.

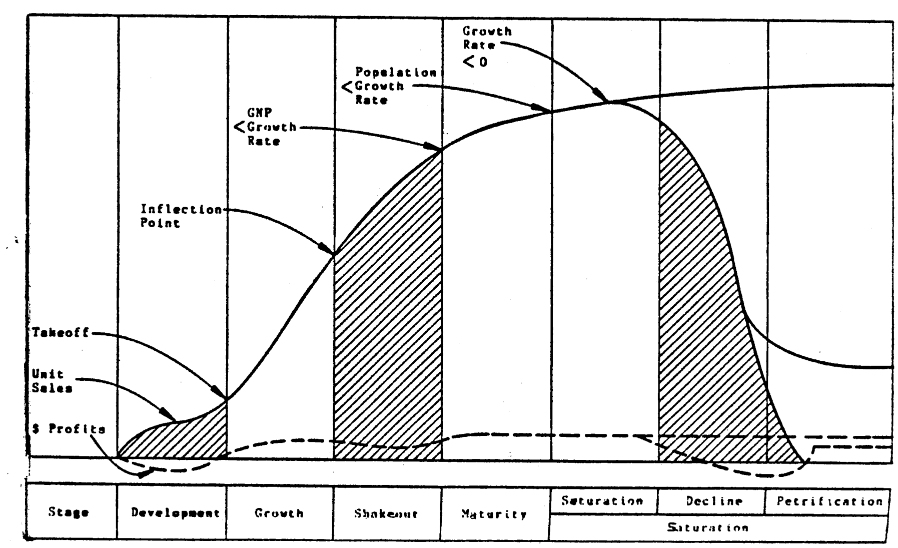


Figure 3.3. Life Cycle Stages
(Taken from Hofer and Schendel, 1978, p. 108)

The study of the product life cycle indicates some of the differences in focus required at the different stages of product/market evolution. During the early stages the emphasis is on innovation, then engineering, production and marketing, finance and distribution. The early emphasis is on effectiveness, but this shifts to an emphasis on efficiency as the market matures.

Attempts have been made to link the product life cycle concept to areas of action for the firm. Life cycles have been quantitatively studied to determine the link between innovation and the life cycle stage. The length of time spent at different stages has been correlated with the "degree of product newness". An innovative new product gives an extended early period with a late peak in the volume of units sold (de Kluyver, 1977). From the degree of newness, a forecast can be made over the shape of the product life cycle curve. Hayes and Wheelwright have focused on the link between the life cycle and manufacturing processes (Hayes and Wheelwright, 1979). This approach emphasizes manufacturing rather than marketing concepts and seeks to fit the production process to the stage in the life cycle. The use of an "inverted product life cycle", has also been advocated (Weber, 1976). This approach looks at the gap between the firm's sales, competitor's sales and the industry market potential sales. Apart from a usage gap, product line and distribution gaps are employed to break down the areas in which improvement is possible.

At the corporate strategy level the product life cycle concept is employed to determine the balanced portfolio of businesses. The simplest approach is the BCG (Boston Consulting Group) matrix shown in Figure 3.4 (Hofer and Schendel, 1978). The axes are the relative competitive position and the growth rate of the industry.

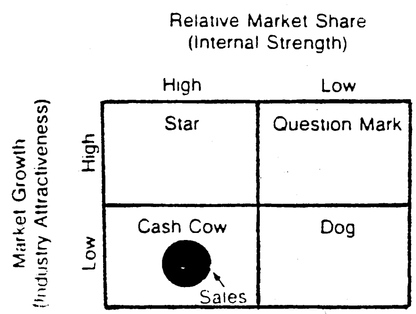


Figure 3.4. BCG Matrix
(Taken from Hax, 1984, p. 20)

Criticisms of the BCG matrix have led to the development of somewhat more sophisticated matrices such as the General Electric Business Screen (Hofer and Schendel, 1978). The competitive position is indicated as strong, medium or weak. High, medium or low are used to indicate industry attractiveness. The area of the circles in the BCG matrix represents the size of the business, while in the GE matrix the area represents the size of the industry and the size of the company's market share is indicated as a "pie slice" within the circle. A modification of the GE matrix to give a 15 cell matrix has been made by expanding the industry dimension to specifically give five dimensions of product/market evolution, namely development, growth, shake-out, maturity and decline. The latter modification is valuable if businesses consist of individual or small groups of related product/market segments. Otherwise, the original GE matrix is superior. The BCG matrix may be used for initial screening to indicate which businesses need closer attention.

According to Adizes (1979), an organization must do four things to be effective. It must produce, administer, be entrepreneurial and integrate. All four roles, PAEI, must be performed well, but there is a different weighting on the roles depending on the position of the company on the life cycle curve.

Products, processes, product areas, companies, businesses and industries all have life cycles. Stages occur during growth, maturity and decline which serve to categorize the relationship between product and market, between company units and processes and between companies. Use of the product life cycle concept allows the best fit of strategy, structure and process to be attempted, (Dumbleton, 1986).

3.2.5.2 Limits of the Product-Process Matrix Framework. Using the product-process matrix as a means for matching process technology and product line decisions has limitations, as does any theoretical construct. While these do not necessarily detract from the usefulness of the concept, it is important to keep in mind the fact that no single framework can ever handle all situations equally well, (Hax, 1984).

For example, the development of flexible machining centers appears to offer firms both low cost and far greater flexibility for product changeovers than do older, less automated, and less capital-intensive processes. Similarly, some of the production practices adopted in Japan as part of "just-in-time" production and materials management systems require higher levels of equipment investment (together with lower machine utilization), but provide significantly increased production flexibility. Such improvements in production flexibility, in the absence of movement along the diagonal, might be thought of as a third dimension to the matrix.

A second example of the concept's limitations is when there is a breakdown in the assumption that a product's life cycle is equivalent to a market life cycle. While the two generally move in the same direction, they do not necessarily move at the same rate or to the same extent.

Another source of divergence between the product life cycle and the market life cycle occurs when the same product is sold into multiple markets. This latter difficulty also occurs when a market splits into price categories, and the products and customers in each major price segment follow separate product life cycles.

3.2.6 Implication of Strategy-Structure for Engineering Design and Manufacturing (ED&M)

Strategy and structure formulations have concentrated on the macroscopic business aspects of the firm. In principle, the ED&M strategy should be consistent with the overall strategy of the company and the structure of the ED&M operation should fit within the ED&M strategy.

The model of Miles and Snow (1981), enables several statements to be made regarding ED&M. A defender organization will place its emphasis in a narrow domain and will aim for continuous improvements in technology to maintain efficiency. Financial and product functions are the most powerful.

Prospector organizations rely on high technology for growth and survival. The most powerful functions are marketing and research. Growth is by product and market development and so the thrust is in innovation. The organization must be flexible and so the tendency will be toward a product orientation.

ED&M in the analyzer organization reflects the dual nature of the business. Miles and Snow predict a low investment in ED&M since imitation of the successful products of others requires speed of action in the engineering sphere. However, marketing and applied research are the most influential functions followed closely by production.

Since the reactor organization does not pursue a distinct, consistent strategy, there is no pattern to the organization.

Although the model of Miles and Snow does give an indication of the general orientation of the organization in terms of strategy pursued, it does little more than to outline the part that ED&M plays in the strategy and how ED&M is structured.

Ansoff and Stewart related the technological profile to the rate of change of the environment and the distance of the technology from the state of the art. Conclusions may be drawn about the ratio of research effort to development effort.

Steele has considered the role of technology in business strategy (Steele, 1975). This is done using a matrix approach. The business strategies possible are hold/harvest, grow the present business or extend the present business. Technology inputs are to apply the state of the art, to extend the state of the art, to use competing technology or to use an alternative technology to supplant the old. This matrix is shown in Figure 3.5. Here the business strategies have been subdivided to give added focus to the strategy employed. The examples indicate different levels of strategy and technology. Steele does not focus on the mission aspects; the emphasis is on product development rather than customer development.

BUSINESS OBJECTIVES / TECHNOLOGY INPUTS	HOLD/HARVEST			GROW PRESENT BUSINESS			EXTEND PRESENT BUSINESS		
	Improved Performance	Improved Cost	New Features	Improved Performance	Improved Cost	New Features	New Level of Value Added	Associated Markets	Associated Technologies
Apply the State-of-the-Art		A							
Extend the State-of-the-Art				B					
Competing Technology Used by Others							C		
New Alternative Technology to Supplement Old									D

A - Reduce shop cost;

B - Redesign bearing to improve life;

C - Produce own magnet wire;

D - Develop linear motor.

Figure 3.5. Technology and Business Strategy Matrix (Dumbleton, 1986, p. 84)

Nystrom has examined the manner in which companies choose new markets and new areas of technology and how the research effort is focused (Nystrom, 1979). Companies are considered to be either positional or innovative in character. Positional companies resemble the defenders of Miles and Snow while innovative companies resemble prospectors. A distinction is made between intended and realized ED & M strategies. Intended strategies are expressed in explicit policies relating to ED & M activities, while realized strategies refer to consistent patterns of behavior which may or may not be the result of implementing policy decisions.

A practical approach to CIM planning is represented in the following phased procedure: (Mize, 1986c)

1. Understand the corporation's and division's strategic business objectives.
2. Analyze and understand the current systems.
3. Correct fundamental deficiencies in the current system.
4. Conceptualize the desired future system, based on the Division's strategic business objectives and knowledge of technological developments and trends.
5. Design a comprehensive, phased migration path.
6. Manage the implementation:
   - Sequence, schedule discrete projects.
   - Provide resources.
   - Implement changes, new systems.
   - Track benefits, measure performance.
   - Modify CIM Plan as necessary.
7. Return to Step 4 (annually).

This is essentially a never-ending process.

All of the above treatments on strategy-structure, the environment and on the product life cycle provide clues to the organization of ED&M and the strategies to be employed. Throughout the whole discussion, the central theme has been that an ED&M strategy must reflect business strategy. This argument is the major concern of the strategic manufacturing planning decision support system discussed in Chapter 7.

CHAPTER IV

GOALS, OBJECTIVES AND ASSUMPTIONS OF THE RESEARCH

As mentioned in the literature review in Chapter 3, research in the area of manufacturing strategic planning was not considered until very recently, as a need to the increasing rate of technological change and increased competition. At present, there is very little work done in manufacturing strategic planning, especially in the area of strategic manufacturing planning decision support systems.

The objectives of this research are as follows:

1. The development of a systematic methodology for accomplishing strategic planning for engineering design and manufacturing, which assures consistency between the manufacturing strategy and the overall strategic business objectives.

2. The development of the structure of a strategic manufacturing planning decision support system (SMP-DSS), based upon the proposed methodology (objective 1, above).

3. The validation of the methodology and decision support system via its application to a modified real world example. Further elaboration of these research objectives will assist in the visualization of the characteristics desired in the resulting methodology and decision support system.

Research Objective One (Methodology)

The systematic methodology for strategic planning for engineering design and manufacturing should reflect the following characteristics:

a) An engineering design and manufacturing strategy which is consistent with and contributes to the overall business strategy. Computer Integrated Manufacturing is to be incorporated as an explicit strategy to achieve strategic business objectives.

b) Product-Process technology is to be a primary element in the industry structure analysis and in the identification of the generic business strategy.

c) Technological life cycle and product life cycle concepts are to be considered explicitly.

d) Selected Measures of Performance (MOP) are to be incorporated into the methodology. These MOP provide information to aid in the evaluation of the manufacturing strategy, and the assurance of its consistency within the overall business strategy. These MOP represent requirements or performance measures for the firm and its competitors. Some of the MOP to be considered are:

- Return on assets (revenue / total assets)
- New business formations (new entrants, $ assets /year)
- Technological areas life cycle status
- Quality of management (consistency of decisions)
- Profitability (marginal contribution / product /year)
- Value added per square meter ($\$/m^2$)
- Quality (raw materials, finished products, process)
- Flexibility (process adaptation to new products)
- Manufacturing velocity (units/time)
- Responsiveness (response time to customer orders)
- Capacity utilization (use of facilities)
- Schedule Performance (internal responsiveness to production programs)
- Inventory turnover per year (times/year)

Research Objective Two (SMP-DSS)

The strategic manufacturing planning decision support system (SMP-DSS) should reflect the following characteristics:

a) It should be derived directly from the proposed methodology (research objective 1, above).

b) It should be based upon an internally logical and consistent hierarchical decision structure which represents the progression of data-dependent decisions at various levels throughout the organization. This structure should be such that information generated at upper levels of the hierarchy are derived from data that is provided at lower levels as input information.

c) The basic input information should be data which is attainable.

d) The SMP-DSS should be implemented as a "user-friendly" management tool, possibly in a micro-computer environment.

e) The resulting outputs of the SMP-DSS should provide the management of the firm with the following categories of information:

   i. An assessment of the firm's performance on the MOP selected.

   ii. An assessment of the overall consistency of the manufacturing strategy with the overall business strategy.

   iii. An assessment of the relative contribution of the firm's manufacturing strategy to the firm's competitive position within the industry.

   iv. Information comparable to the three categories above on each of the firm's major competitors.

Research Objective Three (Validation)

The applicability and validity of the planning methodology and decision support system will be attempted through the use of an extensive amount of data and information from a real world firm. The actual company data will be modified to protect its propietary nature. Realistic estimates will be used for data that is not available. Data for competing firms will be largely estimates, but again, realistic estimates will be used.

Finally, the derived planning methodology and decision support system will be subjected to an intensive "face-validity" check by explaining it in detail to the managers of a real world firm and testing its logic and reasonableness.

The procedures will be modified as appropriate following the validation steps described above.

While no claim will be made that the procedures result in any type of "optimal" solution, this research is designed to provide managers a logical, consistent means of making strategic manufacturing decisions that are measurably consistent with the overall business objectives.

Assumptions

1) It is important to state that since this is a manufacturing strategic conceptual construct, the parallelism with an already validated and accepted general strategy construct, in terms of the generic business strategies used, is a crucial aspect in the validation of this construct.

2) For the purpose of this research, only engineering design and manufacturing strategic decisions are considered.

3) A generic business strategy / manufacturing strategy is defined according to any of the three generic strategies

discussed by Porter, (1985). A relative scale is defined for each generic strategy. Porter's framework of industry analysis has been empirically validated by Dess and Davis (1984).

4) The steel firm, HYLSA, located in Puebla, Mexico, is used as the example to verify and validate the evaluations performed by the system. Therefore, it is necessary to have some specific functions that represent particular aspects of this manufacturing environment.

CHAPTER V

METHODOLOGY FOR ACCOMPLISHING STRATEGIC PLANNING FOR ENGINEERING DESIGN AND MANUFACTURING

The basic characteristic of the match an organization achieves with its environment is called its strategy. The concept of strategy is thus one of top management's tools for coping with both external and internal changes. In this regard, organizations need formalized, analytical processes based on a systematic methodology for formulating explicit strategies. There are several important reasons for the use of such methodology:

1. To aid in the formulation of organizational goals and objectives.
2. To aid in the identification of major strategic issues, and to assure their consistency over time.
3. To aid in the explicit identification of the major competitive advantage strengths.
4. To decide in the allocation of discretionary strategic resources.
5. To guide and integrate the diverse administrative and operating activities of the organization.
6. To assist in the development and training of future general managers.

The methodology and considerations proposed here, are concerned at the business level, specifically with manufacturing strategic planning decisions. The major links with corporate strategic planning at one end, and functional area planning at the other end will be also discussed. At the business level, strategic planning focuses on how to compete in a particular industry or product/market segment. Thus, distinctive competences and competitive advantage are usually the most important components of strategy at this level. Scope becomes less important than at the corporate level and is concerned more with product/market segmentation choices and with the stage of product/market evolution than with the breath or depth of product/market scope. Synergy, by contrast, becomes more important. It focuses on the integration of different functional area activities within a single business.

Business strategic planning is characterized by the introduction of the concept of business segmentation. This is a legitimate form of strategic planning process whenever the corporation is composed of a loosely connected set of unrelated businesses.

Table 5.1 shows some basic characteristics of Corporate, Business, and Functional Strategies. A strategic business unit (SBU) is considered as a business area with an external marketplace for goods and services, whose objectives can be established and strategies executed independently of other business areas. No organization is a pure SBU. There is some relation in some way with other companies segments of the organization.

TABLE 5.1

CORPORATE, BUSINESS, AND FUNCTIONAL STRATEGIES (Taken from Hofer and Schendel, 1978, p. 28)

	Corporate Strategy		Business Strategy	Functional Strategy
Goals & Objectives	Survival Purpose & Mission Overall Growth & Profit Objectives		Constrained Product/Market Segment Growth & Profit Objectives	Constrained Market Share, Technological Leadership, etc. etc.
Relative Importance of Strategy Components	Conglomerates	Related Product Multi-Industry Firm		
Scope	√ √ √	√ √ √	√ √	√
Distinctive Competence	√	√ √	√ √ √	√ √ √
Competitive Advantage	√	√ √	√ √ √	√ √
Synergy		√	√ √	√ √ √
Characteristics of Strategy Components				
Scope	Scope of Business Portfolio & Conglomerate Diversification		Product/Market Segment Matches & Concentric Diversification	Product/Market Development & Product Forms & Brands
Distinctive Competences	Primarily financial, organizational, & technological		Varies with the stage of product/market evolution involved*	Varies by functional area, stage of product/market evolution, and overall competitive position
Competitive Advantage	vs. Industry		vs. Specific Competitors	vs. Specific Products
Synergy	Among businesses		Among functions	Within functions
Major Functional Policy Decisions	Financial policies Organizational policies	Diversification policies Make/buy policies Technological policies Financial policies Organizational policies	Manufacturing system design Product line policies Market development policies Distribution policies R & D policies	Pricing policies Promotion policies Production scheduling policies Inventory control policies Labor & staffing policies
Nature of Resource Allocation Problem	Portfolio problem		Life-cycle problem	Functional integration & balance problem

√ √ √ very important   √ occasionally important

√ √ important   not important

The strategic planning methodology proposed in Figure 5.1 is the result of the selection and identification of critical elements for accomplishing business strategic planning. The elements considered form an integrated set of methodologies and techniques described in this chapter and in Chapter 7. They are presented to facilitate the understanding of the logic of the system described in Chapter 7. The determination of consistent manufacturing[a] strategic decisions with the generic business strategy is the main focus in the development of this methodology. Figure 5.1 presents a general framework that outlines the major elements of the methodology. Section 5.3 presents a discussion of strategic manufacturing issues that are considered in the decision support system explained in detail in Chapter 7.

Figure 5.1 outlines the methodology as a logical sequence of the major milestones to accomplish strategic planning for engineering design and manufacturing.

5.1 The Mission of the Business

An expression of the business purpose, as well as the required degree of excellence to assume a position of competitive leadership, is an essential first step in the

[a] The term manufacturing defined in chapter 3, is equivalent to the engineering design and manufacturing term in this work.

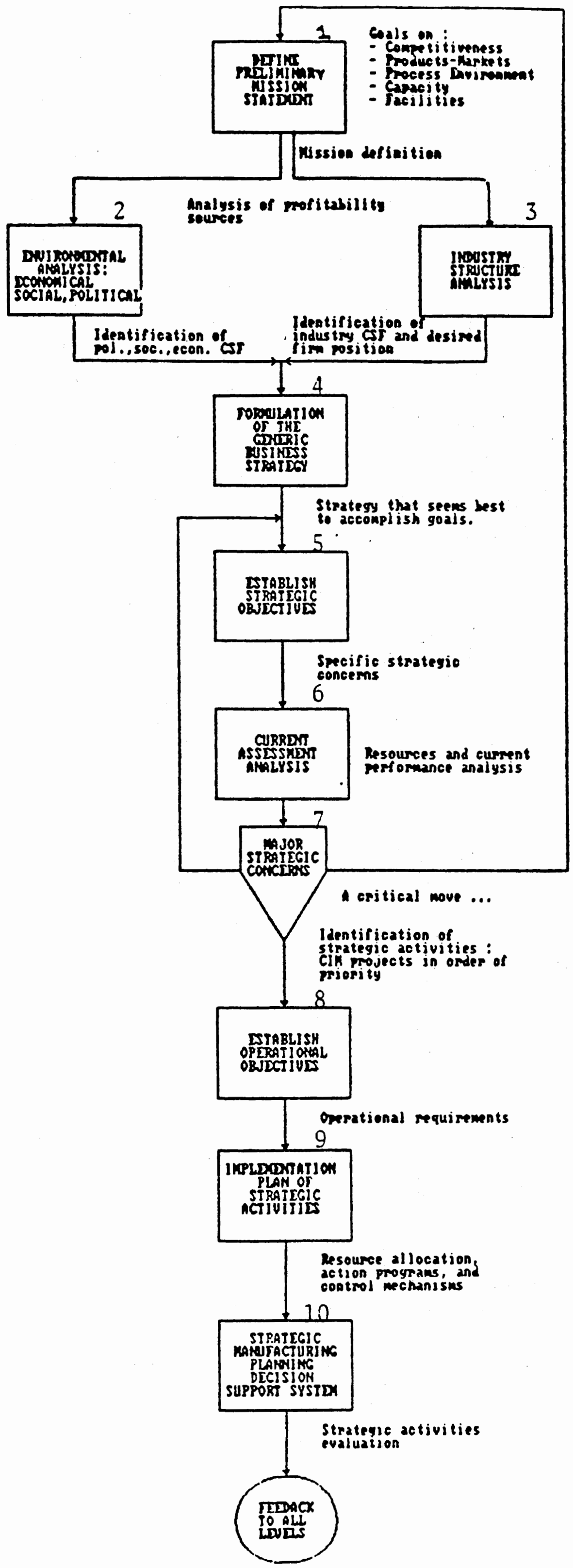


Figure 5.1. A Strategic Planning System Framework.

formulation of a business strategy. This overall statement of business direction is what it is refered to as the mission of the business. The primary information that should be contained in a statement of mission is a clear definition of current and future expected business scope. This is expressed as a broad description of the products, processes, capacity, facilities, geographical coverage of the business today and within a reasonably short period of time, commonly three to five years in stable economies, and from one to three years in inflationary economies, say, greater than 30 % annually.

The specification of current and future products, processes, capacity, facilities, and geographical business scope communicates the degree of permanence that the business is expected to have. It is extremely important to allow for a broad enough definition of business scope in order to detect changes in the industry trends, the repositioning of competitors in terms of products, processes, capacity, facilities, markets, geographical coverage, and the availability of new substitutes.

5.2 Identification and Establishment of a Generic Strategy

Critical Success Factors (CSF) are those variables which management can influence through its decisions that can significantly affect the overall competitive positions of the various firms in an industry. These factors usually vary from industry to industry. Within any particular industry, however, they are derived from the interaction of two sets of variables, namely the economic and technological characteristics of the industry involved. A CSF can be a characteristic such as price advantage; it can also be a condition such as capital structure or advantageous customer mix, product mix, production processes, or an industry structural characteristic such as vertical integration. The concept of critical success factors has been applied at three levels of analysis (firm, specific industry and economic socio-political environment). Analysis at each level provides a source of potential critical success factors.

CSF analysis can aid the strategy development process for environmental analysis, industry structure analysis, resource analysis and generic strategy evaluation (Figure 5.2).

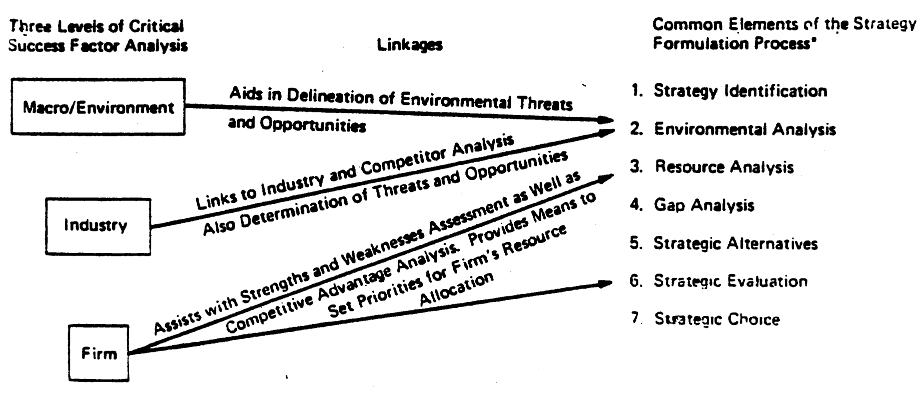


Figure 5.2. Critical Success Factors Analysis (Leidecker, 1984, p. 2)

5.2.1 Environmental Critical Success Factors (CSF) Analysis

Environmental analysis includes an assessment of the social, political, and economic climates and their general impact on an industry and/or firm. It concentrates on assessing the overall economical, political, technological, and social climates that affect the business as a whole. This assessment has to be conducted, first, from a historical perspective to determine how well the firm has mobilized its resources to meet the challenges presented by the external environment; and then, to forecast future trends in the environment and seek a repositioning of the internal resources to adapt the organization to those environmental trends.

The following information is important in the determination of CSF at the environment level (in % for the past 5 years, current, and next 5 years; information with (*) is considered in the SMP-DSS):

- Economic Outlook

  GNP growth, industry contribution to GNP, inflation rate, unemployment, per capita income, prime rate, population growth (*)

- Growth in critical (housing and health) or related industrial sectors

- Growth in primary markets (*)

- Political implications

- Social and legal effects

Environmental analysis is used to identify the significant threats and opportunities facing a firm. Resource analysis involves an inventory of a firm's strengths and weaknesses. It identifies those variables that have been instrumental to a firm's success in a particular industry. This approach leads to a level of sophistication that provides greater depth and insight than a mere listing of a firm's strengths and weaknesses, for assessing a firm's competitive advantage. Strategy evaluation involves comparing strategic alternatives with specific goals and objectives of the firm.

For the purpose of this research, the strategic manufacturing planning decision support system considers only manufacturing strategic information to aid in the evaluation and consistency of the manufacturing strategy within the overall business strategy.

5.2.2 Identification of Industry Critical Success Factors

Identification of industry CSF can be an important element in the eventual development of a firm's strategy as well as an integral part of the strategic planning process. For a review of eight techniques used in the identification of CSF, see (Leidecker, 1984). One such technique is the analysis of industry structure. An adaptation of this technique was selected after analyzing the other seven proposed methodologies to identify and establish the generic business strategy of a firm.

5.2.2.1 Model for Industry Structure Analysis. An adaptation of the framework of analysis set forth in a recent effort by Michael Porter (1984) provides an example of this approach. It consists of five basic forces (barriers to entry, substitutable products, suppliers, buyers and interfirm competition) as determinants of industry profitability which are illustrated in Figure 5.3. The evaluation of each element and the interrelationships between them provide the analyst with considerable data to assist in the identification and justification of industry CSF. An industry will enjoy high and stable profits whenever the firms within that industry can work effectively with their customers to establish accurately the demand pattern over time, deal effectively with the threats of new entrants and substitutes, neutralize the bargaining power of suppliers and customers, and establish a moderate to low rivalry among themselves.

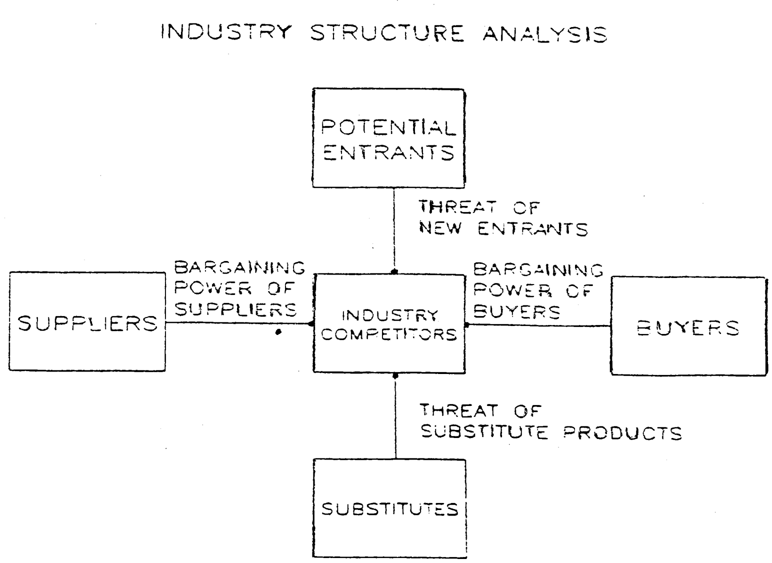


Figure 5.3. Model for Industry Structure Analysis

It is worthwhile to mention briefly the more basic model underlying Porter's before presenting the adapted model for industry structure analysis. The model of industrial organizational analysis is presented in Figure 5.4. The idea behind it is that the basic conditions that regulate supply and demand are the primary determinants of market structure, which guides the actions of all participating firms. Therefore, the observed conduct of firms in the market could be anticipated from the structure prevailing in the industry. Finally, the performance of an industry is considered good when the industry is satisfying the societal expectations with regard to the production of goods and services. Using the factors defined in Figure 5.4, it follows that:

- price behavior,
- product strategy and advertising,
- research and innovation,
- plant investment, and
- legal tactics,

are functions of the prevailing market structure, characterized by:

- number of sellers and customers,
- product differentiation,
- barriers of entry,
- cost structures,
- vertical integration, and
- conglomerateness.

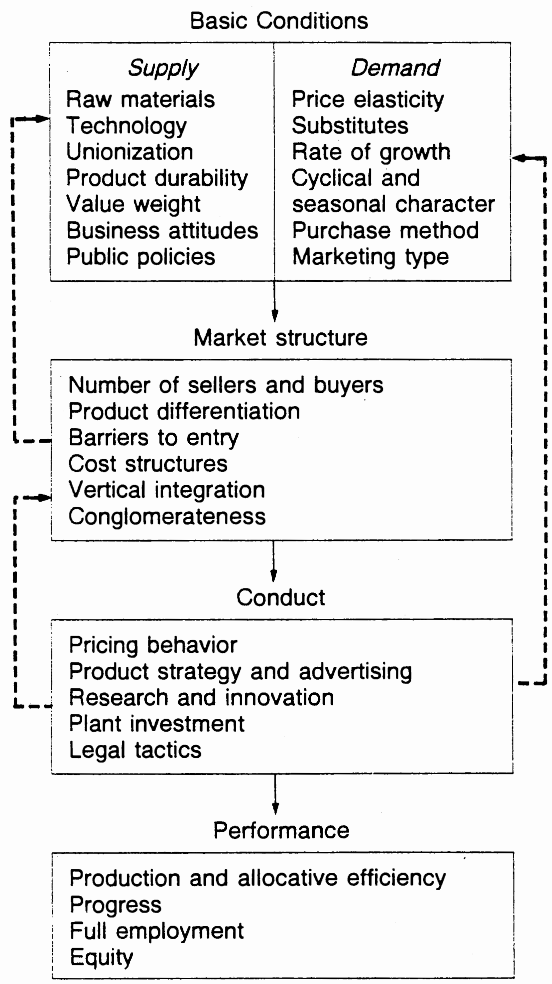


Figure 5.4. A Model of Industrial Organization Analysis (Taken from Scherer, 1980, p. 265)

An effective competitive strategy takes offensive or defensive action in order to create a defendable position against the five competitive forces. Broadly, this involves a number of possible approaches:

- positioning the firm, so that its capabilities provide the best defense against the existing array of competitive forces;
- influencing the balance of forces through strategic

moves, thereby improving the firm's relative position ; or

o anticipating shifts in the factors underlying the forces and responding to them, thereby exploiting change by choosing a strategy appropriate to the new competitive balance before rivals recognize it.

5.2.2.2 Generic Business Strategies. Structural analysis can be used to predict the eventual profitability of an industry. In coping with the five competitive forces, there are potentially successful generic strategic approaches to outperforming other firms in an industry:

1. Differentiation
2. Overall cost leadership
3. Focus

It is important to discuss the idea behind each generic strategy because they are the conceptual basis of some matrices relationships in the SMP-DSS.

Differentiation calls for creating something that is perceived industry-wide as being unique. Approaches to differentiating can take many forms: design or brand name, product/process technology, features, customer service, dealer network, or other dimensions.

Overall cost leadership requires aggressive construction of efficient-scale facilities, vigorous pursuit of cost reductions from experience, tight costs and overhead control, and cost minimization in general, in areas like R&D, service, sales force, advertising, and so on.

Focus consists of concentrating on a particular buyer or customer group, segment of the product-line or geographical market. As with differentiation, focus may take many forms. Although the low cost and differentiation strategies are aimed at achieving those objectives industry-wide, the entire focus strategy is built around servicing a particular target very well, and each functional policy is developed with this in mind.

Strategy is basically aimed at securing a long term sustainable advantage in a competitive market. The three generic strategies discussed above attempt to pursue that goal in quite distinct ways. The justification for this positioning can be understood after recognizing the U-shape effect that is observed in the profitability behavior of firms competing in some industrial sectors. This curve indicates that if a firm can achieve a certain level of sales that allows the exploitation of the full benefits of the experience curve, strategies leading toward cost leadership could truly pay off. If this is not the case, two basic alternatives are still open, one leading toward unique differentiation, where the firm can enjoy a price-premium based on the special character of products offered, and the other is to compete finding a niche by targeting the product to a particular market.

For the purpose of this research, an overall business strategy / manufacturing strategy will be defined according to any of the three generic strategies discussed before. An explicit description of conditions affecting each one of the five forces in Porter's model and the way in which they impact the profitability of industry is presented in Figure 5.5. For a review of a complete discussion of the five original competitive forces, see (Porter, 1984). Only the Technological area and its link to the strategic planning process are presented here.

	PROFITABILITY DECREASES	PROFITABILITY INCREASES
	EASY TO ENTER	DIFFICULT TO ENTER
1. Ease of entry If >	Low scale economies Little brand franchise. Common product/process technology. Low level of computer integrated manufacturing. Access to distribution chanels.	High scale economies. Brand switching difficult. Propietary know how. High level of integration. Restricted distribution chanels.
	DIFFICULT TO EXIT	EASY TO EXIT
2. Ease of exit If >	Very specialized assets. High exit costs. Interrelated business.	Salable assets. Low exit costs. Independent business.
	SUPPLIERS POWERFUL	SUPPLIERS WEAK
3. Power of suppliers If >	Forward integration threat by suppliers. Suppliers concentrated. significant costs to switch suppliers.	Backward integration threat by purchasers. Purchase commodity products. Many competitive suppliers. Concentrated purchasers.
	CUSTOMERS POWERFUL	CUSTOMERS WEAK
4. Power of customers If >	Customers concentrated. Fixed customers purchase a significant proportion of output. Customers posseses credible backward Integration threat.	Producers threaten forward integration. Significant customer switching. Customers fragmented. Producers supply critical portions of customers' input.
	SUBSTITUTION EASY	SUBSTITUTION DIFFICULT
5. Availability of substitutes If >	Low customer switching costs. Substitute producers are aggresive and profitable.	High customer switching costs. Substitute producers are passive and unprofitable.

Figure 5.5. Some Conditions Affecting Industry Competitiveness

	PROFITABILITY DECREASES	PROFITABILITY INCREASES
	MANY COMPETITORS	SMALL # OF COMPETITORS
6. Industry conditions If >	Saturated product markets, slow demand growth. High fixed costs, not flexible process adaptation to new products.	Market growing, fast demand growth. Low fixed costs, flexibility of adaptation to new products
	LESS STRATEGIC LINKS ON CIM	MORE STRATEGIC LINKS ON CIM
7. Product/ process technology If >	Non-strategic areas integrated. Mismatch in product/process technology selection. Technology and industry life cycle are not on the same phase. Automation did not follow simplification.	Main strategic areas integrated. Product/process technology match. Technology and industry life cycle are on the same phase. Simplification, then automation. Firms uses long term, multi attribute technology evaluation methods.

Figure 5.5 (cont.). Some Conditions Affecting Industry Competitiveness

5.3 Adaptation of Product/Process Technology to Framework

Figure 5.6 presents an adaptation of Porter's framework of industry structure analysis. A new block (Product / Process Technology) usually considered secondary, is now incorporated into the strategic planning process. It represents a very important element with the other five to identify the critical success factors that will be the basis for the definition of the generic strategy to be pursued.

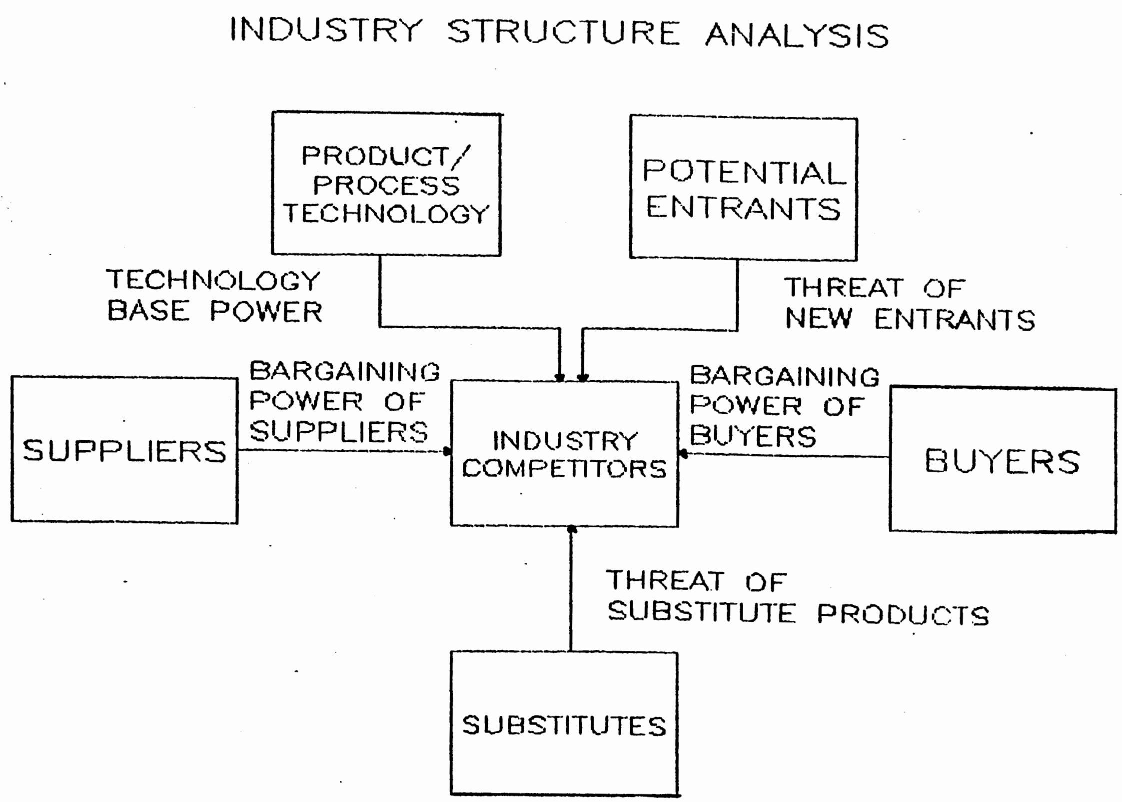


Figure 5.6. Adaptation of Product/Process Technology

An ED&M technology strategy for the purpose of this research will consist of the following four step process:

1) ED&M technology situation assessment. An internal and external scan of the ED&M technology environment.

2) Technology portfolio development and justification. A tool to identify and analyze key business ED&M technology alternatives.

3) ED&M technology and business strategy integration. Integration and evaluation of ED&M technology and business strategy.

4) ED&M technology investment priorities

Figure 5.7 represents the main elements to accomplish the integration and consistency of the manufacturing and the business strategy. It contains the topics covered in the next sections, which present reflections and ideas of logical relationships to accomplish such integration. The blocks above the red line form part of the SMP-DSS described in Chapter 7. The other blocks are considered to be external supporting elements of the system. The development of some of them has already been done at the Center for Computer Integrated Manufacturing in the School of Industrial Engineering and Management, Oklahoma State University (ex., Karacal, Beaumarriage, Sitz, Pacheco, San Roman, Udoka, and Jamoussi master's reports).

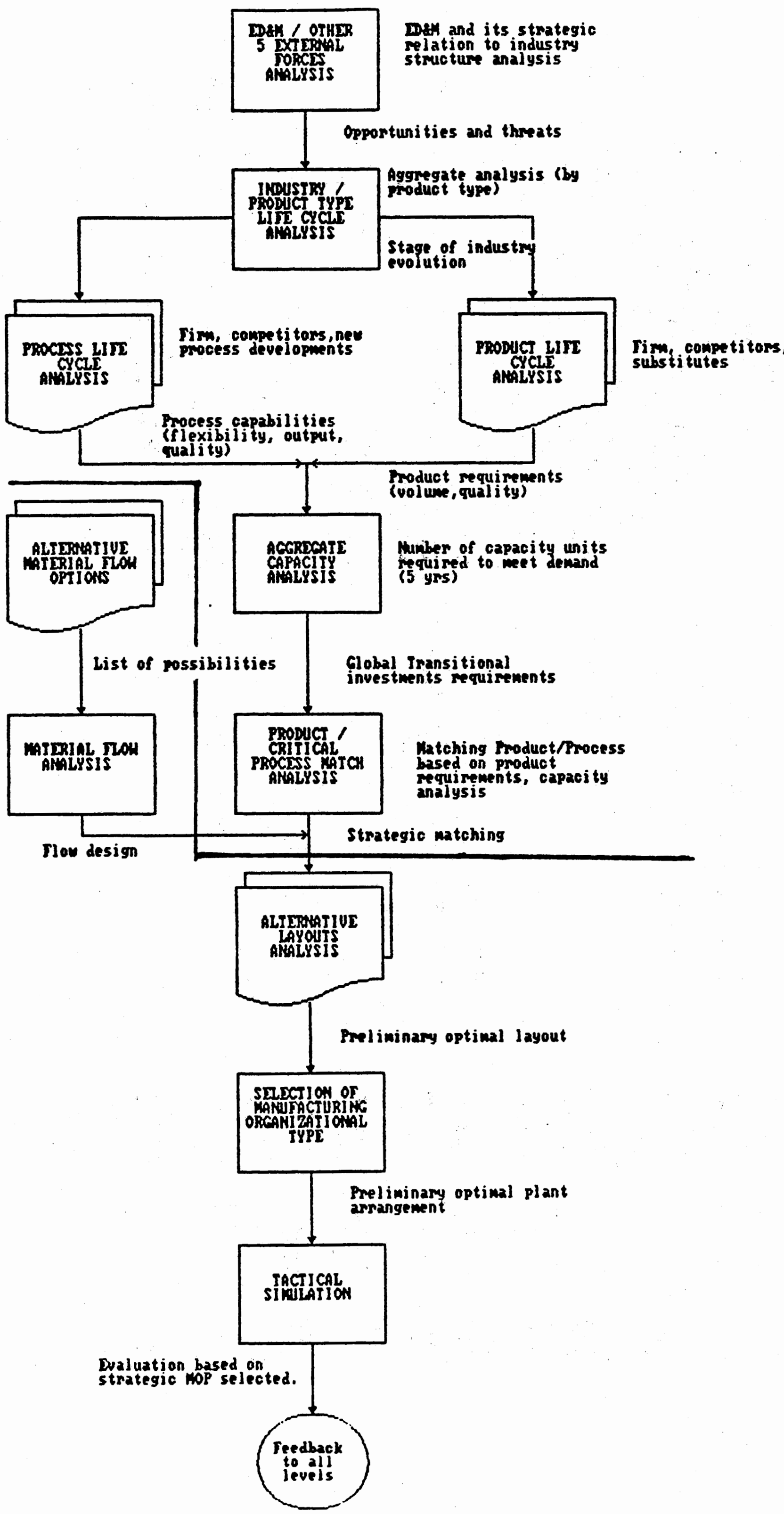


Figure 5.7. Steps to Accomplish ED&M and Business Strategy Integration / Consistency

5.3.1 Manufacturing Technology and the Other Five Forces

Engineering design and manufacturing technology is extremely important, if it affects competitive advantage and industry structure.

- ED&M and Entry Barriers

ED&M technological change is a powerful determinant of entry barriers. It can raise or lower economies of scale in nearly any value activity. For example, flexible manufacturing systems often have the effect of reducing scale economies. Technological change can also raise economies of scale in the technological design and development function itself, accelerating the introduction of a product or raising the investment required for a new model.

ED&M technological change can lead to absolute cost advantages, or could play an important role in shaping the pattern of product differentiation in an industry. ED&M technological change can also raise or lower switching costs.

- ED&M Technology and Buyer Power

ED&M technological change can shift the bargaining relationship between an industry and its customers. The role of technological change in differentiation and switching costs is vital in determining customer power. Technological change can also influence the ease of backward integration by the buyer or customer, a key customer bargaining lever.

- ED&M Technology and Supplier Power

ED&M technological change can shift the bargaining relationship between an industry and its suppliers. It can eliminate the need to purchase from a powerful supplier group or, conversely, can force a firm to purchase from a new, powerful supplier. It could also allow a number of substitute input materials to be used in a firm's product, creating bargaining leverage against suppliers. ED&M technology investments by firms can also allow the use of multiple suppliers by creating in-house knowledge of supplier's process technologies.

- ED&M Technology and Substitution

Perhaps the most commonly recognized effect of ED&M technology on industry structure today is its impact on substitution. Substitution is a function of the relative value to price of competing products and the switching costs associated with changing between them. ED&M technological change creates entirely new products or product uses that substitute for others.

The perception of value by customers frequently changes over time in substitution because time and marketing activity are working to alter the way buyers view a substitute compared to a product.

- ED&M Technology and Rivalry

ED&M technology can alter the nature and basis of rivalry among existing competitors in several ways. It can dramatically alter the cost structure and hence affect pricing decisions. The role of technology in product differentiation and switching costs also is important to rivalry. Another potential impact of technology on rivalry is through its effect on exit barriers, especially on very specialized and capital intensive facilities.

Because of the power of ED&M technological change to influence industry structure and competitive advantage, a firm's ED&M technology strategy becomes an essential ingredient in its overall competitive strategy. However, ED&M technology strategy is an element of the overall competitive strategy, and must be consistent with, and reinforced by choices in other value activities. An ED&M technology strategy designed to achieve differentiation in product performance will lose much of its impact, for example, if a technically trained sales force is not available to explain the performance advantages to the customer and if the manufacturing process does not contain adequate provisions for quality control.

The ED&M technology strategy is a potentially powerful vehicle with which a firm can pursue each of the three generic strategies. Depending on which generic strategy is being followed, however, the character of the ED&M strategy will vary a great deal, as shown in Table 5.2. The SMP-DSS follows the line of reasoning presented in Table 5.2.

After the critical success factors at the environmental level and the industry level have been determined and weighted, it is at this point that a generic strategy can be established, or redefined. As is shown in Figure 5.1, this is an iterative process, since the current assessment analysis, described later could change the magnitude of the intended strategy (it is recommended to read Section 5.4 on current assessment analysis before the rest of this section).

A company should always aggressively pursue opportunities (with net present worth greater than zero) that do not sacrifice differentiation. A firm should also pursue differentiation opportunities with a net present worth greater than zero and evaluated as non-dominated solutions based on multiple criteria. Beyond this point, however, a firm should be prepared to choose what its ultimate competitive advantage will be and resolve the trade-offs accordingly.

TABLE 5.2

PRODUCT AND PROCESS TECHNOLOGY AND THE GENERIC STRATEGIES

	Cost Leadership
1.Product Technology	Engineering product design to reduce product cost and manufacturing cost, to increase efficiency, long cost effective production runs. CIM main goal : minimize overall ED&M strategic product costs.
	Differentiation
	Product design to enhance a characteristic(s) of the product (superior quality), product features, or deliverability in terms of fast response to customer orders. CIM main goal : to achieve superior product quality on specific characteristics, or to optimize product variety or optimize response time to customer orders.
	Cost Focus
	Product design and features are just the necessary ones to satisfy a specific market segment needs. CIM main goal : minimize product cost for a specific market segment.
	Differentiation Focus
	Product design and features are more flexible and superior product quality is a high level objective, meeting the needs of a particular segment better than other firms in the industry. CIM main goal : to achieve superior product quality for a specific market segment, on a specific characteristic(s), optimize product variety or optimize response time to customer orders.

TABLE 5.2

(Continuation)

	Cost Leadership
2. Manufacturing process technology.	Process improvements to reduce product cost, to enhance economies of scale (long cost effective production runs). CIM main goal : minimize overall ED&M strategic manufacturing process costs.
	Differentiation
	Process development to support tighter tolerances, superior process quality, more reliable scheduling, faster response time to customer orders, and in general any activity that increases the perception of value by the customer. CIM main goal : to achieve superior process quality on specific characteristic(s) or, optimize flexibility in manufacturing to adapt to new markets or, optimize response time to customer orders.
	Cost Focus
	Process development and features are just the necessary ones to satisfy a specific market segment needs. CIM main goal : minimize process costs for a specific market segment.
	Differentiation Focus
	Process design and features are more flexible and superior process quality is a high level objective, meeting the needs of a particular segment better than other firms in the industry. CIM main goal : to achieve superior process quality on specific characteristic(s) or optimize flexibility in manufacturing to adapt to new markets or, optimize response time to customer for a specific market segment.

The R&D program of a cost leader, for example, should include projects designed mainly to lower costs in all value activities, that represent a significant fraction of the product cost, as well as projects to reduce the cost of product / process design and manufacturing.

5.3.2 Criteria for Evaluating a Manufacturing Strategy

A manufacturing strategy in terms of a pattern of decisions is evaluated based on the following criteria:

1) Consistency (internal and external)

   1.1 Between the manufacturing strategy and the overall business strategy

   1.2 Between the manufacturing strategy and the other functional strategies within the business

   1.3 Among the decisions categories that make up the manufacturing strategy

2) Contribution (to competitive advantage)

   2.1 Evaluating the relative contribution of the manufacturing strategy to the achievement of competitive advantage

5.3.3 Competitor Analysis

The purpose of the competitor analysis at the business level is twofold:

(1) to identify those areas where the firm has advantages over competitors that may be exploited and,

(2) to identify those areas where competitors have advantages which they may be able to exploit

Competitor analysis requires identification of major competitors and their past and present objectives, strategies, key ED&M technologies, other resources, and major strengths and weaknesses, so that reasonable assessments can be made about their potential future business objectives and strategies.

The SMP-DSS considers competitor's information as the basis to compute the competitive advantage of the firm, if any, with respect to the measures of performance selected.

A very important issue a firm must address in ED&M technology strategy is whether to seek technological

TABLE 5.3

TECHNOLOGY LEADERSHIP AND FOLLOWER TRADE OFF FACTORS

Leadership (innovative strategy)
- Makes relatively obsolete existing labor skills, manufacturing facilities, and vertical integration commitments, while requiring new investments for replacements
- May undermine successful product standardization and modularization policies
- Unfamiliar technology, high start up costs, and production uncertainties may conflict with ongoing cost reduction strategy efforts
- Raises unanticipated problems in quality, cost, inventory control, and workforce planning
Follower (imitative strategy)
- Affords maximum use of existing facilities, processes, and vertical integration investments
- Designs usually can be made compatible with existing product line and standardization strategies
- Presents less manufacturing and quality problems

leadership. The notion of technological leadership is relatively clear - a firm seeks to be the first to introduce ED&M technological changes that support its generic strategy. The choice of whether to be a technological leader or follower in an important technology is based on the sustainability of the lead and the advantages or disadvantages for being the first to adapt a new technology. Table 5.3 shows the tradeoffs of technological leadership and followers.

5.3.4 Life Cycle Concepts Applied on this Research

5.3.4.1 Industry Evolution and Segmentation. Since ED&M technological change has such a powerful role in competition, forecasting the path of its evolution is extremely important to allow a firm to anticipate technological changes and thereby improve its position. Most research on how technology evolves in an industry has grown out of the product life cycle concept. Technological change early in the life cycle is focused on product design innovations, while the manufacturing process remains flexible. As an industry matures, product designs begin to change more slowly and mass production techniques are introduced. Process innovation takes over from product innovation as the primary technological strategy turns to achieve minimum cost of an increasingly standardized product. Finally, all innovation slows down in later maturity and declines as investments in the various technologies in the industry reach the point of diminishing returns. This pattern does not apply to all industries.

In summary, recent research and theory development suggest that both the magnitude and the type of opportunities and threats that a business faces vary according to the stage of evolution of the industry in which it competes and its competitive position within that industry. Consequently, the stage of product/market evolution provides an indication of the investment potential of the business and also of the relative emphasis that needs to be given to the business's various functional area strategies. These ideas provide some guidelines applied in the SMP-DSS to determine the consistency of strategies at various levels in an organization.

One of the greatest sources of new strategic opportunities is the development of new market segments. Market segmentation refers to the fact that, at any point in time, different consumers may possess different economic, physical, and psychological needs that cause them to buy and use particular products differently. In terms of economic theory, different demand functions characterize each segment. Since a market segment is a group of customers that is large enough to serve economically in a differentiated fashion, it is possible to identify the formation of such segments by tracking the dissatisfactions that current customers have to existing products. When an increasing number of customers express dissatisfaction with the same factor, it usually means that a new segment is forming, unless, of course, the factor in question is truly defective in some way. During the shake-out, maturity, and saturation stages of product/market evolution, new segments often can be identified through a Product Performance Profile (PPP) analysis.

Changes in buying needs, tastes, and usage patterns derive from different sources, like 1) changes in the customer's environment, 2) changes in the customer's abilities, capabilities or resources, and 3) changes in the customer's business or personal strategies. Although such changes are difficult to forecast, it is important to do so for the firm's major customers.

One of the critical elements in the SMP-DSS is the product-market evaluation module, which examines product attributes and logistics characteristics performance (cost, availability, packaging, responsiveness, life cycle, and social acceptance) from the customer's viewpoint. The PPP in combination with the rest of the industry structure analysis would lead to the identification of the CSF. This is illustrated in Figure 5.8. Each of these generic product appeals must be carefully tailored to the product or service at hand - to see the product as the customer sees it. The customer must be carefully defined as well. The formal analysis of the PPP approach is accomplished with the use of simulation and a multicriterion weighting method, explained in Chapter 7.

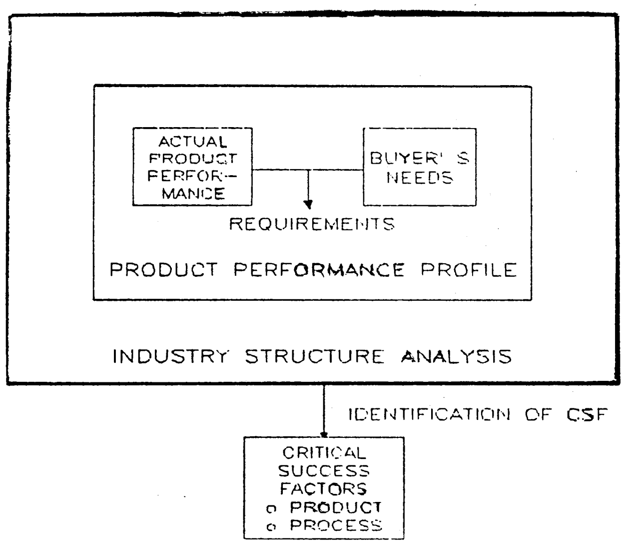


Figure 5.8. Product Performance Analysis

5.3.4.2 Product Life Cycle and Manufacturing Technology. The SMP-DSS contains matrix information with regard to the stage of the product(s) and process(es) life cycles. Therefore, it is important to present the guidelines to follow in the selection of the appropriate position in the corresponding matrix. These guidelines and a discussion of important reflections are presented in the following sections.

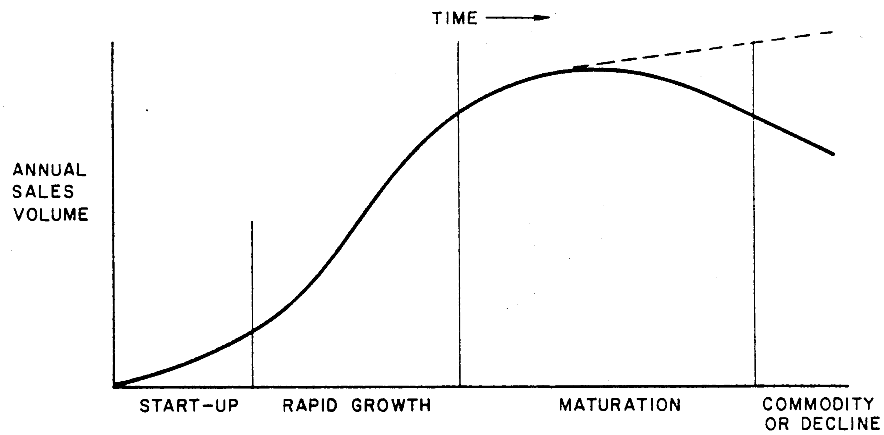
A very important aspect of the product life cycle that has a direct impact on manufacturing has to do with the nature of industry competition and the firm's major competitors. Figure 5.9 suggests that the maturation of a market generally leads to fewer competitors, increasing industry concentration, and competition based more on price and delivery than on unique product features.

As the competitive focus shifts during the different stages of the product life cycle, the requirements placed on manufacturing (in terms of cost, quality, flexibility, and response time to customer orders) also shift. The computer integrated manufacturing system requirements also changes with the stage of the product life cycle. That is, the superior economical systems that the CIM system should include (from design to manufacturing and, the production planning and control system (MPCS)) are influenced by the stage of the business life cycle, which in a way focusses the manufacturing strategic choice.

The stage of the product life cycle affects the product's design stability, the length of the product development cycle, the frequency of engineering change orders, and the commonality of components. All of which have implications for the computer integrated manufacturing system in place, mainly, in economic terms, for the manufacturing process technology.

The product life cycle concept provides a framework for thinking about both a product's evolution through time and the kind of market segments that are likely to develop at various points in time. It also highlights the need to change the priorities that govern manufacturing processes behavior as products and markets evolve.

Table 5.7 indicates that a process life cycle begins with a very flexible production process, but not very cost efficient.



PRODUCT VARIETY:	GREAT VARIETY	INCREASING STANDARDIZATION	EMERGENCE OF A "DOMINANT DESIGN"	HIGH STANDARDIZATION "COMMODITY" CHARACTERISTICS
PRODUCT VOLUME/ MODEL:	LOW VOLUME	INCREASING VOLUME	HIGH VOLUME	HIGH VOLUME
INDUSTRY STRUCTURE:	SMALL COMPETITORS	FALLOUT AND CONSOLIDATION	FEW LARGE COMPANIES	"SURVIVORS"
FORM OF COMPETITION:	PRODUCT CHARACTERISTICS	PRODUCT QUALITY AND AVAILABILITY	PRICE AND DEPENDABILITY	PRICE

Figure 5.9. Characteristics of the Product Life Cycle Important to Manufacturing Technology (Taken from Hayes, 1984, p. 203)

Then it proceeds toward increasing standardization, mechanization, and automation until it becomes very

TABLE 5.7

IMPORTANT ELEMENTS TO CONSIDER IN MANUFACTURING

BY STAGE OF THE PRODUCT LIFE CYCLE

Stage	Inputs
Start	Raw materials and parts used as available from supplier. Characteristics and quality vary widely. Limited influence over supplier.
	Process Characteristics : Technology
	Equipment and tools used as available from industry, unless innovative technology. Product process flow needs careful management control.
	Process Characteristics : Labor;and MPCS
	In general, workers have a broad range of skills. Flexibility in workers's tasks. MRP is an appropriate MPCS.
	Size, Scale
	Capacity is not well defined. Usually low volumes are achieved. Low levels in learning curve effects. In general, few barriers to entry into industry segment.
	Product
	Variety of products with different features and quality. Design changes occur very often. Market is price inelastic.
	Desired CIM System Characteristics
	The CIM system components (product design, process design, MPCS, facilities, etc.) should be very flexible and economically integrated, to allow for radical changes in the way the system integrates such elements. CIM system performance should conform to the manufacturing strategy selected at this stage of the product life cycle.

TABLE 5.7 (CONTINUATION)

Stage	Inputs
Growth	Suppliers are strongly dependent. Raw materials quality is a determinant factor for success.
	Process Characteristics : Technology
	Level of automation varies within the manufacturing process. Integration of processes is required to achieve higher levels of output.
	Process Characteristics : Labor;and MPCS
	Tasks are more structured and standardized. Specialization becomes more important. Maintenance and the manufacturing planning and control system are very critical at this stage.
	Size, Scale
	Capacity is increased, and more accurately defined. The critical decision of moving to a more continuous, high volume manufacturing type of environment is faced at this stage.
	Product
	A more focused variety of products with different features and quality are available to the market. Market is usually more sensitive to price. Design changes still occur at this stage.
	Desired CIM System Characteristics
	A more efficient and economical integrated system is required at this stage, to allow for higher production volumes. However, the manufacturing strategy selected would dictate the trade-offs in cost, flexibility of adaptation to new products, response time to customer orders, etc. CIM system performance should conform to the manufacturing strategy selected.

TABLE 5.7 (CONTINUATION)

Stage	Inputs
Mature	Supplier process is integrated into over-all process design. Raw materials are optimized to fit to process design. Most of the processes that are not cost effective are subcontracted.
	Process Characteristics : Technology
	It is critical at this stage that the manufacturing processes be economically integrated, to meet expanding demand and to compete with other mature firms in the same industry. It is common to have integrated systems based on the current process only, without considering the in-coming new products and processes. Licensed technologies are usually at this stage the dominant firms.
	Process Characteristics : Labor; and MPCS
	Worker's tasks are very rigid, and a very important management concern. Maintenance and the MPCS are also very critical at this stage. JIT is an appropriate MPCS.
	Size, Scale
	Manufacturing facilities are expanded to achieve full scale economies.
	Product
	A very narrowed (cost effective) variety of products is available if price competition is prevalent or a standard type of products if sensitive product differentiation is in effect present. Volume is higher and market is price sensitive.
	Desired CIM System Characteristics
	A very efficient and economical integrated system is required at this stage, to achieve the advantages of the firm's manufacturing strategic position, which should include a relatively high capital intensive efficient production system.

efficient, but much more capital intensive, interrelated, and hence less flexible than the original fluid process.

The description of the process life cycle can be very useful in manufacturing planning and decision making, but it also can be used at a general management level to relate specific manufacturing capabilities to various stages of the process life cycle. For example it can be used to predict how the product's manufacturing cost per unit is likely to change over time. The first stage in the development of a process technology has the characteristic of job shop. It is flexible, economically efficient to deal with low volumes, if it has few rigid interconnections. As the process matures, it passes through intermediate stages that may involve decoupled line flows (batch processes) and/or assembly lines. Eventually, the process technology may evolve into a continuous flow operation with high throughput volumes, low rates of process innovation, and less flexibility due to high levels of automation and vertical integration.

5.3.5 The Two Extremes of Industries

The previous section leads to the discussion of two broad classes of industries- process or continuous versus fabrication / assembly- because the differences between them have important implications in terms of choice of strategy for ED&M and the way the SMP-DSS determines its consistency at the business level. Typical examples of process industry products include chemicals, refined petroleum and metal products, foods and beverages, and paper goods. Fabrication/assembly products encompass, for example, automobiles, home furnishing, machine tools, electrical equipment, computers and industrial machinery.

The differences between these two categories include product/market characteristics, the nature of the production equipment, inputs to the production process, and other manufacturing characteristics.

5.3.5.1 Product and Market Characteristics. The contrast in product and market characteristics can be seen in Table 5.4. Clearly, there are significant differences between the two types of industries. In particular, because of the more standardized nature of products in the process industries, there tends to be more production to stock, as opposed to order, than there is in fabrication/assembly.

TABLE 5.4

PRODUCT/MARKET CHARACTERISTICS

	TYPE OF INDUSTRY	
CHARACTERISTICS	PROCESS	FABRICATION/ASSEMBLY
Number of customers	Less	More
Number of products	Less	More
Product differentiation	More standardized	More customized
Marketing characteristics	Availability/price	Features of products
Demand for intermediate products	Higher	Lower

5.3.5.2 The Nature of the Equipment and Inputs. Considering inputs as raw materials, manpower, and energy, there are important differences between the two industry groups. From Table 5.5, it can be appreciated that process industries tend to be more capital intensive. Process industries tend to have a flow-type layout; that is, materials flow through various processing operations in a fixed routing. However, particularly in fabrication, the flow is by numerous, different, and largely unconstrained paths. However, the use of the concept of group technology, tends to lead to a significant amount of flow layout even in fabrication. This concept will be described later. The production lines in the process context tend to be dedicated to a relatively small number of products with comparatively little flexibility to change either the rate or the nature of the output. In this environment, capacity is quite well defined by the limiting or bottleneck operation, whereas with fabrication/assembly both the bottleneck and the associated capacity tend to shift with the nature of the work load (which products are being produced and in what quantities).

Because of the relatively expensive equipment and plant involved and the relatively low flexibility in output rate, process industries tend to run at full capacity. This and the flow nature of the process necessitate highly reliable equipment, which, in turn, normally requires substantial preventive maintenance. Moreover, much longer lead times are typically involved in changing the capacity in a process industry, partly because of environmental concerns, but also because of the nature of the plant and equipment involved.

The number of raw materials used tends to be lower in process situations as compared with fabrication/assembly; in fact, coordination of raw materials, components, and so on, as well as required labor input, is a major concern in fabrication/assembly. However, there can be more natural variability in the characteristics of these raw materials in the process context.

TABLE 5.5

NATURE OF INPUTS

	TYPE OF INDUSTRY	
CHARACTERISTICS	PROCESS	FABRICATION/ASSEMBLY
o Capital versus labor/material intensive	Capital	Labor/material
o Level of automation	Higher	Lower
o Nature of production layout	Flow	Job shop or flow
o Flexibility of output	Less	More
o Capacity	Well defined	Vague
o Lead times for expansion	Higher	Lower
o Reliability of equipment	Higher needs	Lower needs
o Nature of maintenance	Shutdown	Component basis
o Number of raw materials	Lower	Higher
o Variability of raw materials	Higher	Lower
o Energy usage	Higher	Lower

5.3.5.3 Other Manufacturing Characteristics. Other manufacturing characteristics are illustrated in Table 5.6. Although there may be relatively few products run on a particular flow line in the process industries, the products do tend to group into families according to a natural sequence to achieve better coordination and interrelationships. As a consequence, in contrast with fabrication/assembly, a major consideration is given to the appropriate sequence and the time interval between consecutive cycles among the products. The relative similarity of items run on the same line in the process context also makes it easier to aggregate demand data, running hours, etc, than is the case in fabrication / assembly.

TABLE 5.6

OTHER CHARACTERISTICS

	TYPE OF INDUSTRY	
CHARACTERISTICS	PROCESS	FABRICATION/ASSEMBLY
Family of items	Primary concern	Less concern
Aggregation of data	Easier	More difficult
Work in process-inventory	Lower	Higher
Yield variability	Higher	Lower
By-products	More	Less
Need for traceability	Higher	Lower

The flow nature of production in the process industries leads to less work-in process inventories than is the case, for example, in the job shop context of fabrication. This relative lack of buffering stock, in turn, implies a crucial need for adequate supplies of the relatively few raw materials, as well as reliable equipment. However, in this case the same line of reasoning applies to high-volume assembly lines.

There can be considerable yield variability in certain operations in process industries. Thus, variable mixes of products or ingredients and running times are more common in process than in fabrication/assembly industries.

There tends to be more by-products in process situations. Finally, the nature of certain process industries requires lot tracing- the ability to ascertain which materials were used and under what conditions as each output unit is produced.

5.3.6 The Product-Process Matrix

The product life and process life cycle stages cannot be considered separately. One cannot proceed from one level of mechanization to another, for example, without making some adjustments to the products and management decision systems involved. Nor can new products be added or others discontinued without considering the effect on production process utilization changes. Hayes and Wheelwright (1984) summarized their empirical research into a graphical representation known as a product-process matrix. Silver (1985) provides an adapted version suggested by Schmenner (1981) that is portrayed in Figure 5.10.

The columns of the matrix represent the product life cycle phases, going from the great variety associated with startup products on the left-hand side, to standardized commodity products on the right-hand side. The rows represent the major stages through which a production process tends to pass in going from a relatively fluid to a highly standardized form. Most production organizations find themselves more or less along the diagonal. A number of illustrations are shown in the figure. Fabrication is in the top left corner, process industries toward the bottom right corner, and assembly in the middle. However, there are some exceptions. For example, drugs and specialty chemicals, which are process industry products, are centrally located whereas containers and steel products, which involve some fabrication, are toward the bottom right.

Hayes and Wheelwright discuss the strategic implications of nondiagonal positions.

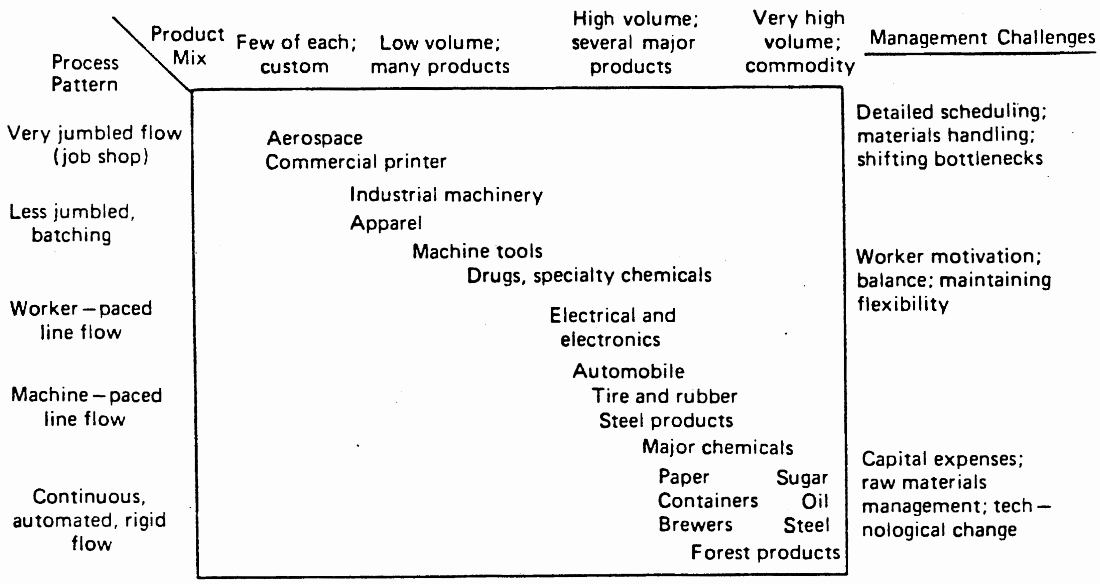


Figure 5.10. Product/Process Matrix (Taken from Silver, 1985, p. 32)

The strategy for production planning, scheduling, and inventory management should depend on how easily one can associate raw material and part requirements with the schedule of end products. Actually there is a direct connection between the position on the product-process matrix and the ease of the mentioned association. In the lower right-hand corner of Figure 5.10, the association tends to be quite easy (continuous flow systems). This position is, by and large, occupied by capacity-oriented process industries. As one moves up to the left and passes through high-volume assembly into lower volume assembly and batching, the association becomes increasingly difficult. In this region one is dealing primarily with materials and labor-oriented fabrication/assembly industries.

5.3.6.1 Matching Products and Processes Over Time. It is more common to find diagonal matches, in which a certain kind of product structure (set of market characteristics) is paired with its natural process structure (set of manufacturing characteristics). However, a business may seek a position away from the diagonal in order to differentiate itself from its competitors. This may or may not make it more vulnerable to attack, depending on its success in achieving focus and exploiting the advantages of such a niche.

Not only can the use of a product-process matrix help make explicit a firm's distinctive competence, it can also help it avoid the dangers of product or process proliferation. Introducing a new product or entering a new market, either in an attempt to increase the utilization of existing facilities or simply to take advantage of the apparent profitability of a customer request for a modified product, can lead to a continually expanding line - in effect causing the business unit to move horizontally to the left on the matrix. In an effort to stimulate demand a company enters a new market or introduces a new product. While this move may be successful, the existing process technology is incapable of meeting this added scale and complexity without additional investment. Within the context of the product-process matrix, the business finds itself trying to move along one dimension while not adequately adjusting its position on the other. Eventually it is forced to move along the other dimension as well. If this represents an expansion of its process, for example, adding a job shop to what is essentially an assembly line process, rather than an overall repositioning of its manufacturing strategy, the company's manufacturing focus would tend to be diluted, making it more difficult to match the success that other firms are able to achieve with the proper manufacturing environment.

This scenario is also observed when an industry leader finds its standardized product line being challenged by smaller firms who attempt to segment the mass market and target specialized forms of the product for different segments. Over time such competition may slowly erode the leading firm market share to the point where its relatively high volume, standardized process is no longer economical. In an attempt to counterattack, it may introduce specialized products of its own, moving to the left in the matrix, only to find that its process technology cannot compete effectively with competitors who have focused their process technologies around the specific volume and product characteristics best suited to each segment of the market.

5.3.6.2 Implications of Different Positioning Strategies. The main competitive advantage of a job shop process is its flexibility to both product and volume changes. As a firm moves toward more standardized process technologies, its distinguishing capabilities shift from flexibility and customization to product reliability, and cost. In general, a company that chooses a given process structure can reinforce the characteristics of that structure by adopting the corresponding product structure.

For a given product structure, a company whose competitive strategy is based on offering customized products or features and rapid response to market shifts should tend to choose a much more flexible production technology than would a competitor that has the same product structure but follows a low-cost strategy. The former approach positions the company above the matrix diagonal; the latter positions it along or below the diagonal.

A company that chooses to compete primarily in the upper left, has to decide when to drop a product or abandon a market that appears to be progessing inexorably along its product life cycle toward maturity, while a company that chooses to compete in the lower right must decide when to enter that market, because there is more economical risk.

A company that takes into consideration the process dimension when formulating its competitive strategy can usually focus its operating units much more effectively on their individual product lines. While a fairly narrow focus may be required to succeed in any single product market, large companies generally produce multiple products for multiple markets. These products are often in different stages of their life cycles. Such companies can benefit by separating their manufacturing facilities, and organizing each to meet the specific needs of different products, having different layouts, equipment, workforce organization, and MPCS. Each facility meets the needs of a specific segment of the market. Companies seem to be most successful when they organize their manufacturing function around either a product/market focus or a process focus, but not both. That is, individual operating units respond directly to the needs of the particular markets they serve, or else they should be divided according to process stages (for example, fabrication, and assembly) and coordinated by a central staff.

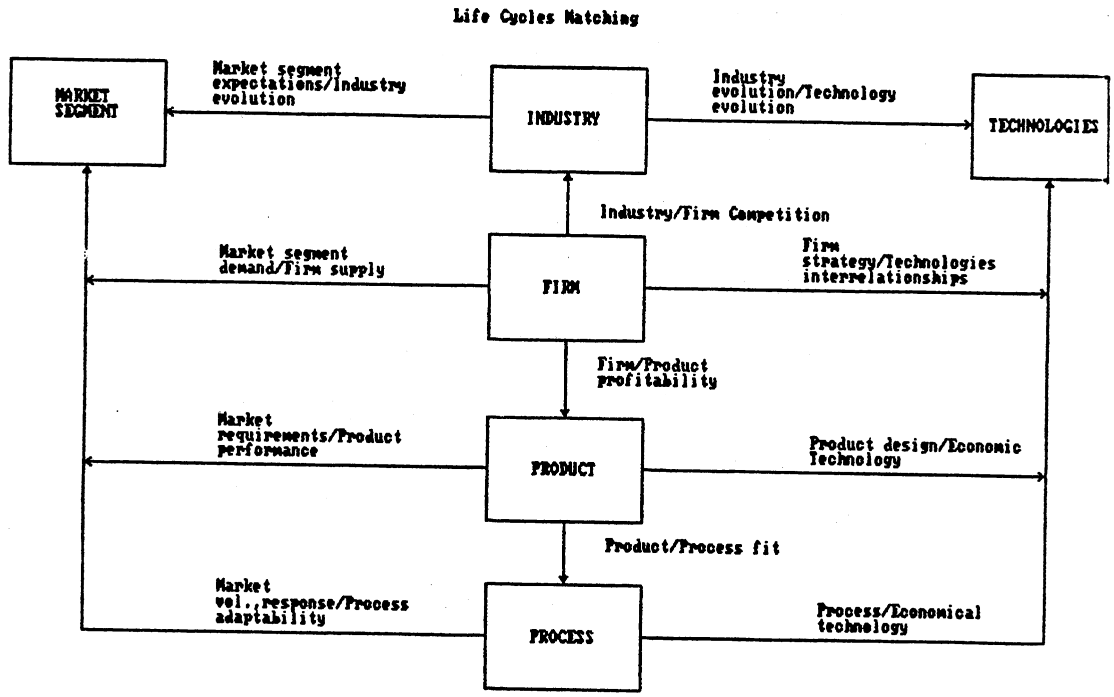


Figure 5.11. Life Cycles Matching

A corporation should be engaged in looking for the optimal overall strategic match among the, industry / firm / market segment / Technologies / Product / Process life cycles (Figure 5.11), to maximize the long term sustainability of its strategic goals.

5.3.6.3 Adding a Flexibility Dimension. The recent development of flexible manufacturing systems offers firms the achievement of low cost and greater flexibility of adaptation to new products. Such improvements in production flexibility, in the absence of movement along the diagonal, might be thought of as a third dimension to the matrix. This dimension would represent increased overall effectiveness without a major change in the basic match between product life cycle and process life cycle, providing more manufacturing strategic positions available. The companies positioned down on the flexibility axes, would have more competitive advantages than a firm situated in the matrix, with the same product/process match but lower level of flexibility, if the additional investment evaluation results are positive.

5.4 Current Assessment Analysis

The next step in Figure 5.1 would be to perform an assessment of the current ED&M activities, considering the cost or unique drivers related with the highest weighted critical success factors encountered in the environmental analysis and in the overall industry structure analysis. The assessment of the current situation should include all the activities that are performed to design, produce, market, deliver and support a product. Porter 1985, uses the concept of value chain to describe such activities, but at the same time are directly or indirectly of value to the customer. Differences among competitor value chains are a key source of competitive advantage. Cost drivers determine the cost behavior of value activities. Uniqueness drivers are the underlying reasons of why an activity is unique.

The SMP-DSS focusses on manufacturing aspects, to analyze the effect of different manufacturing strategic decisions. To accomplish an effective assessment of the current ED&M situation, the IDEFO (ICAM, 1980) methodology would be very helpful in understanding the structure of the manufacturing system. Improvement functions are then evaluated for integration into technological areas based on some criterion. Also, non-financial criteria are evaluated for each major technological area. Technological areas are then ranked in order of priority, using a weighted method. A steering committee would then select, assuming resource constraints, the main areas of concern associated with the most critical success factors. At this point, systems methodology could be used in the development of any project. The evaluation of tactical and operational proposed changes to the manufacturing system would be mainly obtained by keeping an updated simulation model, comparing the results with the actual operation of the system. These results constitute the feedback information of the tactical and operational levels to the SMP-DSS at the strategic level. The firm will be evolving and integrating intelligent decisions at the right time.

A description of the systematic approach for the development of the structure of the SMP-DSS is presented in Chapter 6. The SMP-DSS is explained in detail in Chapter 7, reflecting the concepts presented in this chapter. Chapter 8 contains the results of the example used for the verification and validation of the system.

CHAPTER VI

GENERATOR OF HIERARCHICAL SYSTEM STRUCTURES (GEESSI)

6.1 GEESSI Philosophy

GEESSI was implemented on a microcomputer and it was adapted to develop the Strategic Manufacturing Planning Decision Support System (SMP-DSS). GEESSI was designed as an information system development tool using APL, to aid in the generation and implementation of hierarchical system structures. This means that the data base matrix type information is used to generate information at higher levels, using the information at previous levels obtained directly from the data base or from calculations, or algorithms attached to a specific relation or matrix.

6.2 GEESSI Characteristics

GEESSI is considered to be an adequate tool for developing hierarchical system structures due to the following characteristics:

- Any application using GEESSI evolves from basic matrix input information, its relationships with external systems, and internal calculations to obtain different levels of information for managerial decision making

- It contains modular front-end programming to generate the structure of the system

- It is a conversational system,
  - o modular
  - o modular creation of files
  - o self documenting

- The main concepts that the system uses are:
  - a) relations
  - b) files
  - c) internal logic of operation of GEESSI
  - d) flexibility to change the structure of any application
  - e) module's independence

a. Relations

A relation, is a two dimensional matrix that contains numeric information. The collection of n relations ordered in a logical hierarchical way appropriate to the application constitute the structure of the hierarchical information system.

Each input or output relation has the following characteristics :

- Relation description
- Dimension
- Row concepts or designators
- Column concepts or designators

Figure 6.1 illustrates the elements of a relation. Appendix B and C contain the complete set of relations used in this research.

```
                    <RELATION NAME>
            Expected Demand by product by year
            ----------------------------------

                   <COLUMN CONCEPTS>
<ROW CONCEPTS>  Product 1   Product 2   Product 3
     Years     ---------------------------------
      1987
      1988
      1989             <RELATION INFORMATION)
      1990             <DIMENSION : (5,3)>
      1991
               -----------------------------------
```

Figure 6.1. A Relation and its Components

b. Files

In GEESSI, two types of files are defined, work space files and data base files. The work space files contain the unchanging GEESSI functions and information that by its nature does not change often, like :

- GEESSI intrinsic functions (Appendix A)
- General operating tables, related to all relations
- Particular operating tables, dealing with relations

The data base files contain the variable information and the calculating functions that generate output relations.

c. Internal logic of GEESSI

GEESSI considers all the relation information defined in the input module as level zero in the hierarchy. The system provides the capability to establish the physical link among relations and to execute the simulated environment in the logical order specified for the particular application. The latter is accomplished through the interaction of GEESSI functions and the evaluation matrix.

The evaluation matrix describes the relations that are calculated, the level of calculation for each relation, and the function number that performs the evaluation. GEESSI's evaluation module executes relations in ascending order based on the relation level number. What GEESSI executes in ascending order are the specific functions that determine the results or values of a specific relation.

d. Flexibility to change the structure of an application.

GEESSI provides a module to change the structure of a system. It allows modifications, additions or deletions to the relation names, concepts names, row concepts of a relation, column concepts of a relation, format of a relation, or the evaluation matrix to specify the function or level of calculation. Section 7.5 presents the details of this module.

e. Module's independence.

GEESSI is divided into 4 main modules :

1. Input
2. Evaluation
3. Output
4. Data base creation and structure definition

Chapter 7 presents an application using GEESSI. Each module is interactive, menu driven and independent of each other. This means for example, that the evaluation of the system is not performed unless that option is selected and executed.

The following sequence of activities are required for the correct use of GEESSI :

1. Data Base creation
2. Generate general and individual operating tables, (structure of the system)
3. Generate functions or programs that evaluate each relation
4. Input information for zero level relations
5. Evaluate the system
6. Output of any relation

Details of menus, and names of operating tables appear in Appendix A. The general operation of GEESSI is presented in Figure 6.2.

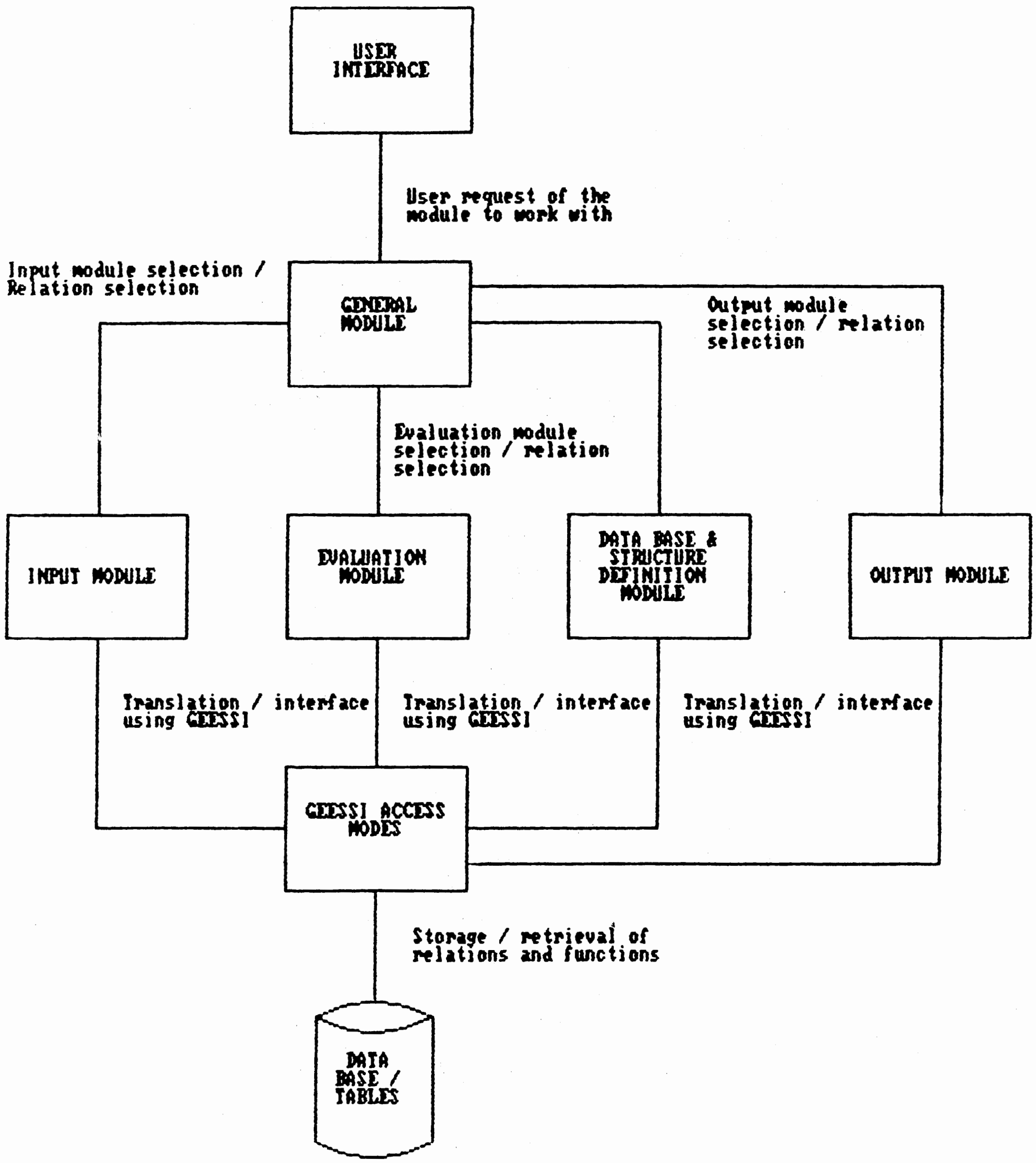


Figure 6.2. General Operation of GEESSI

CHAPTER VII

A STRATEGIC MANUFACTURING PLANNING DECISION SUPPORT SYSTEM (SMP-DSS)

7.1 Introduction

The SMP-DSS is designed with the purpose of helping managers in strategic manufacturing planning decisions. It was developed using GEESSI and APL on a microcomputer. It basically monitors actual performance, compares to the original business strategic plan, and evaluates the strategic impact of the potential corrective action or changes to the system.

It also gathers intelligence information about competitors mainly with the purpose of defining the relative contribution of a firm's manufacturing strategy to competitive advantage.

7.2 Overall System Structure

7.2.1 System Considerations

The system considers some of the elements described in the strategic planning framework in Chapter 5, summarized in Figure 5.1. It supports the industry structure analysis task as well as the environmental analysis which are the most important factors affecting the vital decision of formulating a generic business strategy.

It is important to remark that the SMP-DSS evaluates the effect that manufacturing strategic decisions have on the business as a whole. That is, the impact over time on the financial, market, and strategic position of the firm.

The major manufacturing considerations of the system are concerned with :

1. Product (s)
   - o Requirements
   - o Performance
   - o Life Cycle Status
2. Process (es)
   - o Requirements
   - o Capabilities
   - o Performance
   - o Life Cycle Status

The balance and income statements are the primary sources of information used to perform the competitive advantage analysis, which is described in detail in Section 7.5.

The system supports the environmental scanning analysis described in Chapter 5, specifically, about the economy and its impact on the firm, by providing the means for gathering information pertinent to the industry in question.

The inclusion of the major competitors' information permits the comparison and evaluation of company moves which generate more conclusive and valuable decisions, at the expense of getting such information.

7.2.2 Design Approach

At the business strategic level, it is extremely difficult and maybe unrealistic to formulate a single mathematical model that could capture the complex and subjective factors prevailing at such level. Therefore, it was decided that a decision support system providing the flexibility to manipulate and evaluate a specific set of factors of the strategic planning framework presented in Chapter 5, would be more valid and realistic.

The basic idea behind the SPM-DSS, is to start with matrix information describing the relation between two concepts (ex. product-demand), called level zero. The information at level zero is then used as the input to generate higher levels of information by using basic matrix operations, simulation models, multicriteria techniques and other tools described later. The information of higher levels is then used to generate relations at higher levels, and so on, using functions which contain the logic of the techniques selected to evaluate the relations.

The Generator of Hierarchical System Structures (GEESSI) described in Chapter 6, is the software used and adapted for the implementation of the SMP-DSS. All the modules are menu-driven. Figure 7.1 presents a general diagram containing the building blocks of the SMP-DSS hierarchy; notice the three possible ways of assessing the

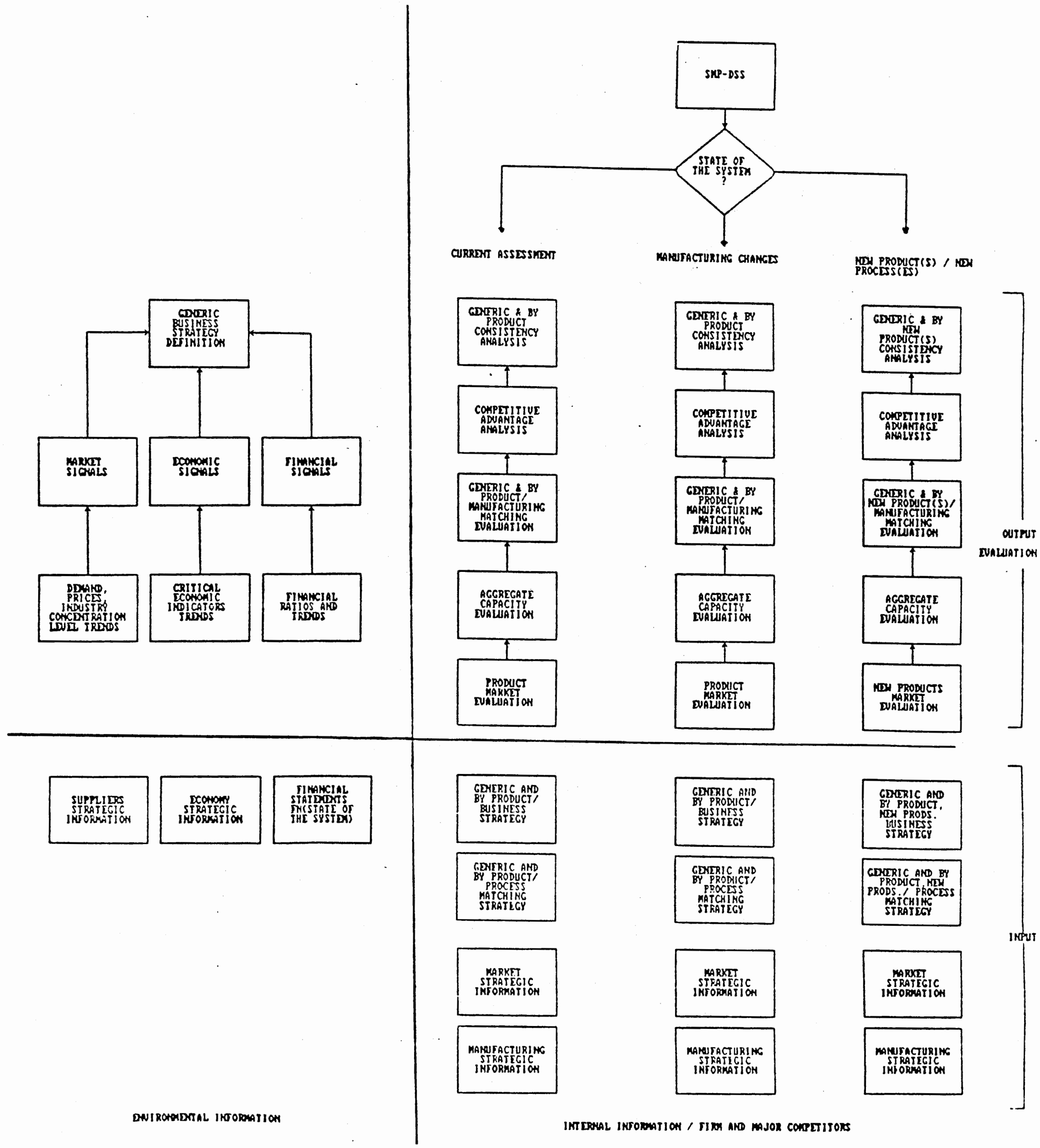


Figure 7.1. SMP-DSS Hierarchy Building Blocks

state the system. The explanation for each of the blocks is described in following sections of this chapter.

The SMP-DSS evaluation functions are designed in most cases for generic use; however, it is important to state that the strategic information and the measures of performance to consider for each real case are different. It is the responsibility of a strategic planning committee to resolve this vital concern. A very specific environment, discussed later, was used for the verification and validation of the SMP-DSS. The definition of each MOP is given throughout the exposition of this chapter.

7.2.3 General Description of the Operation of the SMP-DSS

The internal operation of the SMP-DSS follows the same conceptual guidelines of GEESSI described in Chapter 6. It is important to remark on the modular concept and the order of execution in GEESSI which provide a very flexible way for the operation of the SMP-DSS.

Figure 7.2 shows a simplified version of the operation of the system, if the current assessment of a firm is desired.

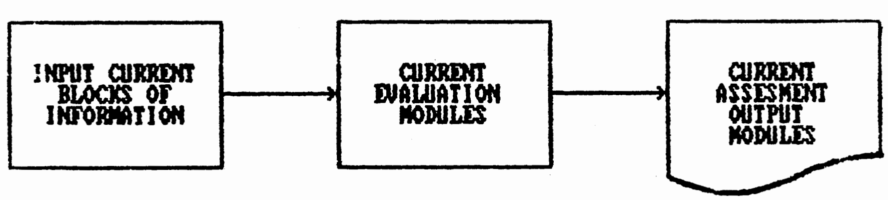


Figure 7.2. Current Assessment of a Firm

Any input matrix from any module can be changed, to evaluate the impact on matrices at higher levels in the hierarchy. Usually modifications to the actual manufacturing environment involve expected net cash flows which also have to be entered in "now dollars" by year in the cash flow matrix.

The present worth of the inflated cash flows discounted at K^* (see Section 7.4.1.3) is used to adjust the financial statements to obtain the pro-forma statements by year. The decision maker has the responsibility to adjust the financial statements by year, so that the net effect on each statement for year i (i=1988,...,1993) corresponds to the present worth of year i. Figure 7.3 represents a simplified diagram of the operation of the system. The SMP-DSS provides independent input and output matrices or relations as well as functions associated to each output relation.

The approach considered for the evaluation of the introduction of new product(s)/process(es) differs from the one presented in Figure 7.3 in that the external systems require the consideration of the new product(s). This basically means: 1) to build a new facility, 2) to modify and adapt the current facility according to the desired product mix, or, 3) if the current manufacturing facility is technologically adequate, decide whether or not to decrease the production of certain product(s) or to increase capacity to maintain a desired level of performance across the business product line.

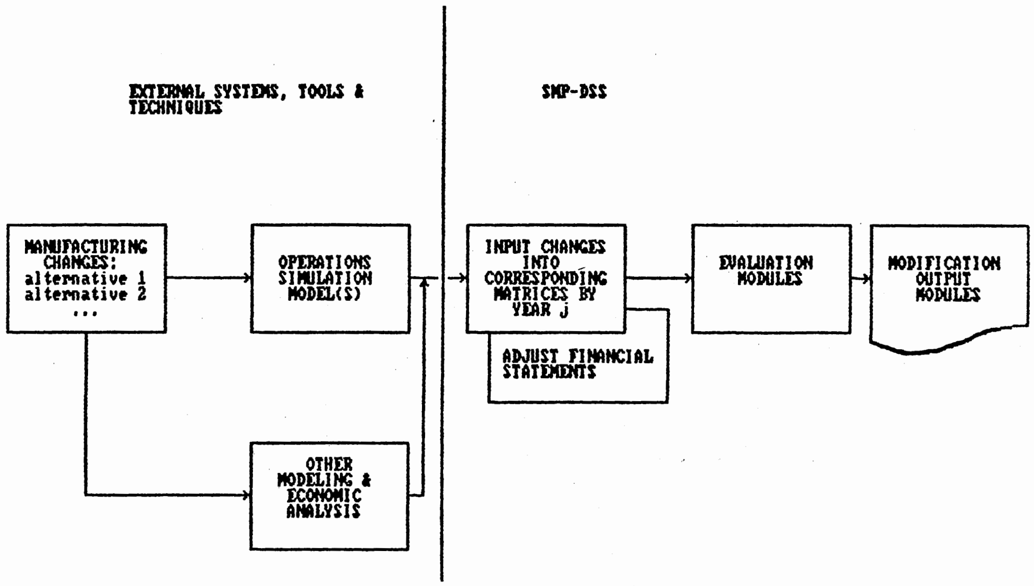


Figure 7.3. Manufacturing Changes and the Relationship between the SMP-DSS and External Systems.

The SMP-DSS utilizes independent input and output relations as well as independent functions for the evaluation of the relations associated to the introduction of new product(s)/process(es). Figure 7.4 shows the general operation just described.

The description of the detailed operation of the system is given in the following sections. Figures 7.2-7.4 show only one level of the hierarchy. The conceptual way the SMP-DSS integrates the different levels of the hierarchy is analogous to the "n Transfer Function System" model presented by (Mize,...,1971) at the strategic level. An overall description is presented next, considering the extension that can be associated to such model. For a detailed explanation see (Mize,...,1971).

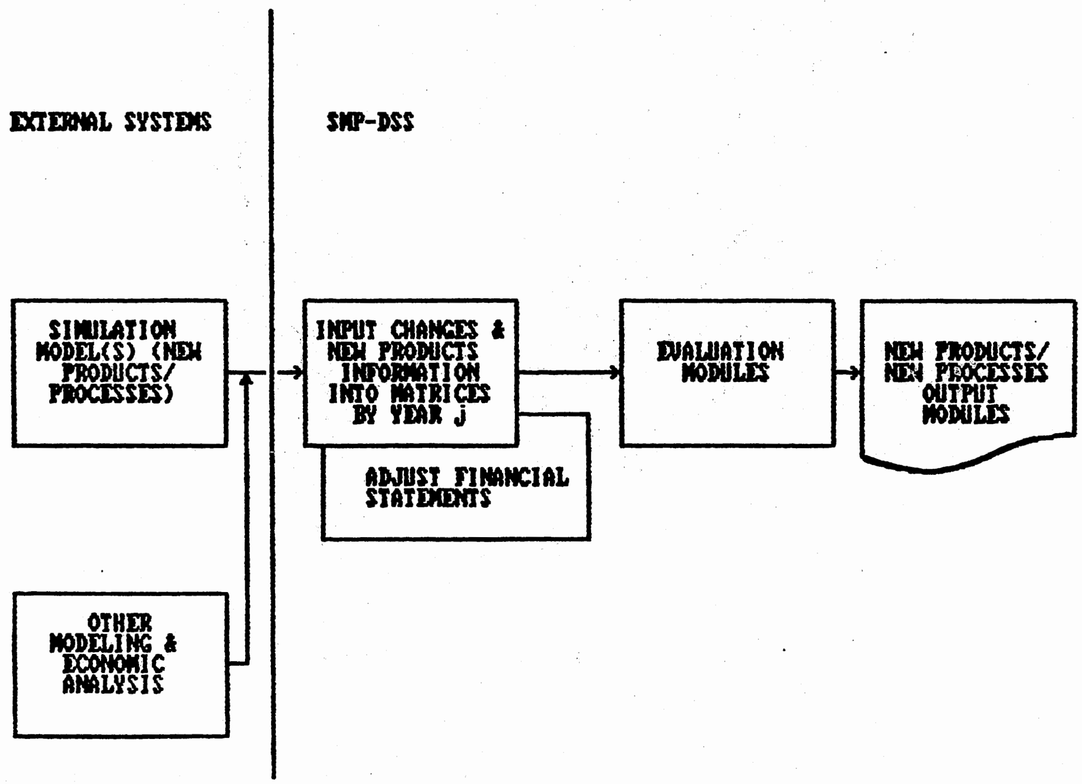


Figure 7.4. General Diagram of the Operation of the System when New Product(s)/New process(es) are Introduced.

A classical concept in electrical engineering is that of a "transfer function". This term is used to denote the functional relationship between input and output of various electrical system components. The term transfer function in a still broader sense represents all decision processes, mathematical or otherwise, in a control system.

Conceptually, a decision process consist of three basic elements:

Input: the information available
Output: the decision required
Transfer Function: The process by which the input is converted to a decision

- The input may consist of new data feedback from operations, a previous decision, and parameters
- The output (the decision) may become input to another decision process
- The transfer function may be of many forms, such as:

  - o a mathematical expression
  - o a linear, nonlinear, or dynamic programming model
  - o a statistical analysis procedure
  - o a tabular procedure (e.g., Gantt chart)
  - o a decision rule
  - o a simulation or other computer model
  - o a heuristic procedure
  - o human judgment
  - o a combination of the above

Figure 7.5 presents the conceptual model of n transfer functions.

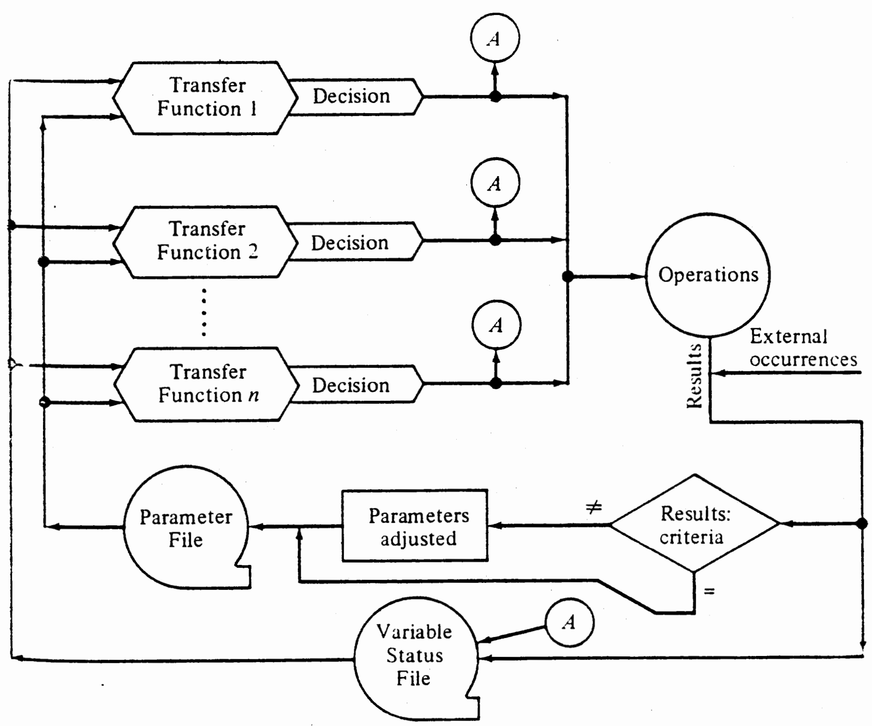


Figure 7.5. Operations Control System of n Transfer Functions (Mize, 1971, p. 33)

7.3 SMP-DSS Input Modules

The input modules considered by the SMP-DSS are:

1. Business strategy master relations	
2. Product/process strategy master relations	
3. Economy	
4. Finance	(firm and competitors)
5. Product(s)/market(s)	(firm and competitors)
6. Suppliers	(firm and competitors)
7. Manufacturing	(firm and competitors)

Each input module is independent and contains built-in check-input functions.

7.3.1 Business Strategy Master Relations

The definitions and relations in this module are:

1) Definition of the generic strategy and the strategy by product

2) Definition of MOP to consider and its weights

3) Definition of master relations

As was stated in Chapter 5, the SMP-DSS assumes that a set of generic business strategies are available of which only one the business unit should pursue aggressively, especially when compromise situations arise and a decision has to be taken.

The SMP-DSS considers a maximum of 12 generic business strategies. The generic business strategies described in detail in Chapter 5 are used in this case:

1. Overall Cost-High
2. Overall Cost-Medium
3. Overall Cost-Low
4. Differentiation-High
5. Differentiation-Medium
6. Differentiation-Low
7. Focus Cost-High

8. Focus Cost-Medium
9. Focus Cost-Low
10. Focus Differentiation-High
11. Focus Differentiation-Medium
12. Focus Differentiation-Low

Each major strategy category (Cost, Differentiation and Focus) is expanded to detect intrinsic shifts within the strategy. "High" for all cases means the "best" achievement of the original generic strategy, (ex., Overall Cost-High means a high positive achievement of the overall cost strategy). So for the cost strategy, in master relations, "High" means the requirements to achieve the "minimum cost" strategy; and for differentiation, the requirements that the strategic planning committee sets to achieve the strategy. Such a committee has to define the current intended generic business strategy and redefine it when manufacturing changes or new products are introduced.

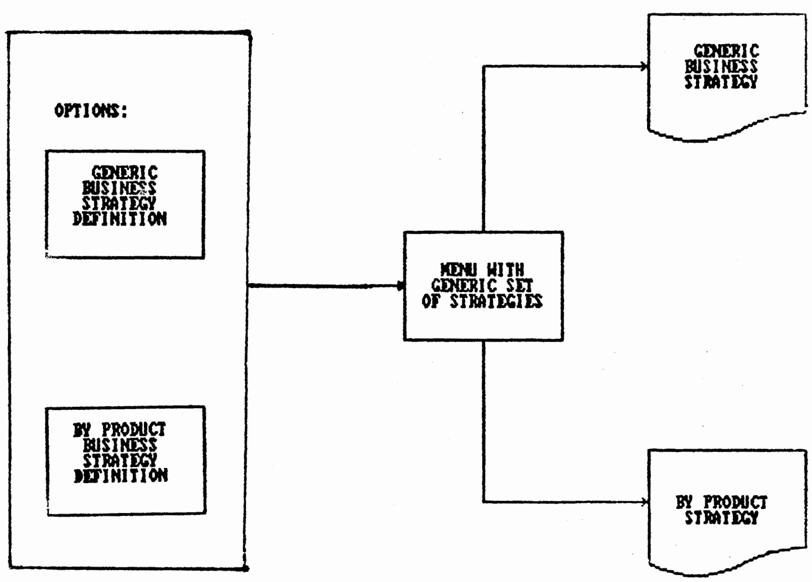


Figure 7.6. Generic and by Product Strategy Definition

Different strategies might be in effect for different products. Therefore, the system provides also the strategy definition by product, and the corresponding evaluation capability which is described in Section 7.4. Figure 7.6 shows how the generic and by product strategy names are defined in the SMP-DSS.

The generic business and by product strategies established are then to be mapped into the manufacturing environment in consideration, given that a measure of consistency is desired between the manufacturing strategy and the overall business strategy. For such an intriguing task, it is proposed,

a) to select economic, financial, market and manufacturing indicators or measures of performance that could capture first the essence of the firm's relation with the environment and, second that could contrast or compromise the choice among the set of generic strategies.

b) a range of acceptance is then set for each measure of performance for each strategy. The matrix that results is called the master relation.

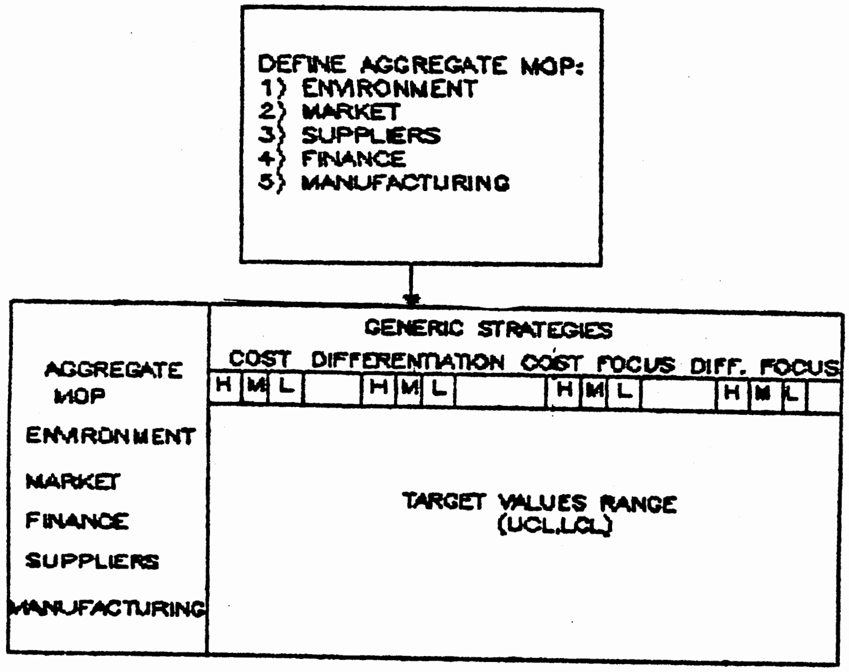
c) the same logic is applied ((a) and (b)) for the,

1) current assessment of the consistency between the manufacturing strategy and the business strategy,
2) the manufacturing changes consistency analysis or,
3) the new product(s)/process(es) consistency analysis.

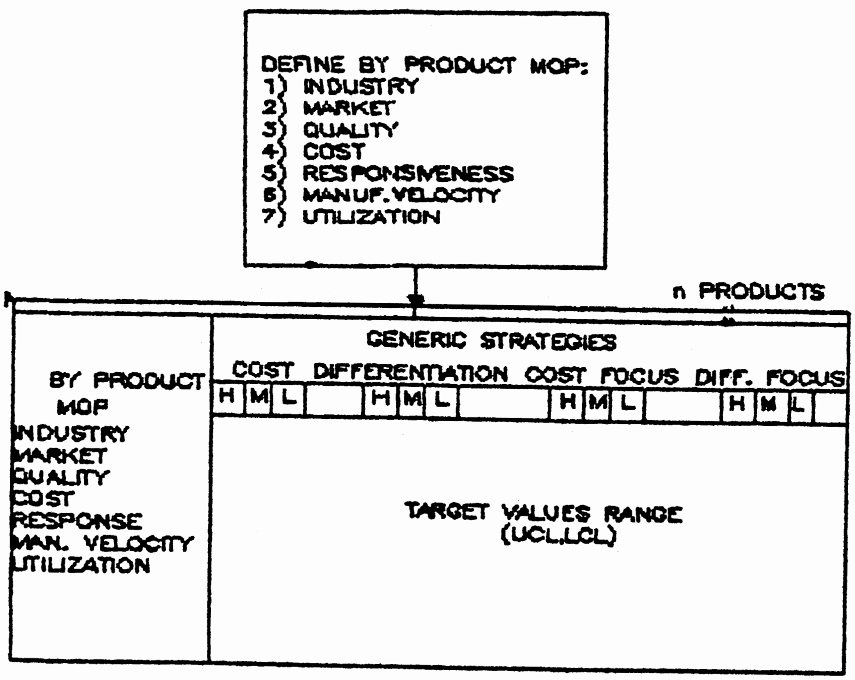
For each one of the three cases, two main groups result:

- The generic business strategy master relations
- The by product strategy master relations

Figure 7.7 presents the general concept.



(a) Generic Business Strategy Master Relations



(b) By Product Strategy Master Relations

Figure 7.7. Master Relations

The importance of each MOP in the generic and the by product master relations is considered in the SMP-DSS, by assigning them weights ($\Sigma = 100$). Separate relations exist for each state of the system.

It is possible to establish generic MOP for different functional areas. However, it is often the case that the definition of the specific measures of performance and information to consider depend basically on two factors. First, they depend on the environment prevailing at the moment and the expected projections, and its strategic impact on the business. Second, they are industry dependent, in the sense that some MOP are more meaningful in one industry than in other. This is specially true in volatile economic environments.

The business strategy master input relations for the steel company HYLSA used as a real example for the verification and validation of the SMP-DSS appear in Appendix B, Section 1. The information utilized in the system is a combination of estimations, realistic information obtained through the author's consulting experience of the last three years and, guidelines from the Corporate Planning Director.

7.3.2 Product/Process Matching Strategy

Master Relations

The definitions and relations in this module are:

1) Product/process matching definition
2) MOP to consider and its weights
3) Master relations

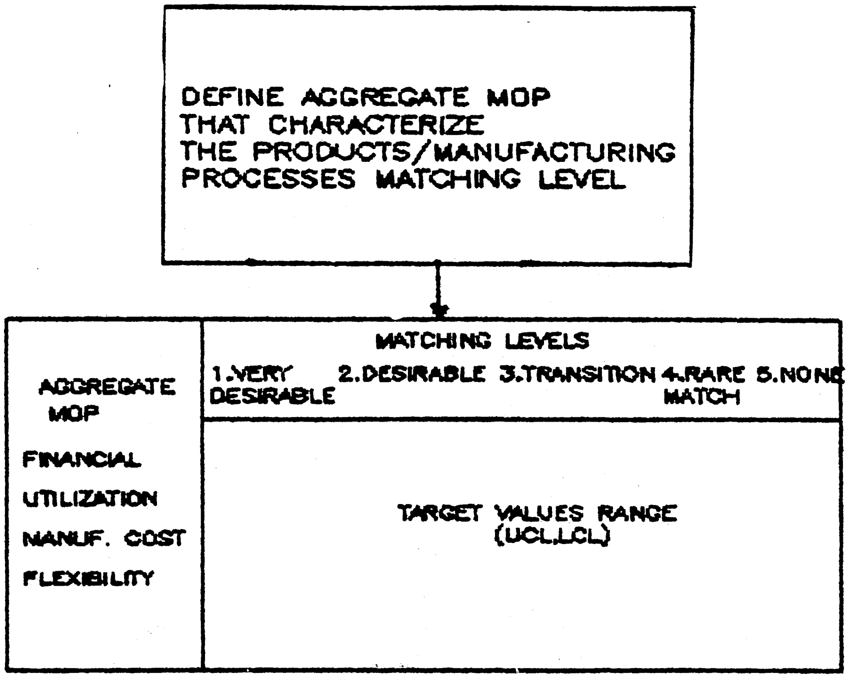
The actual or expected results of the match between a product and a manufacturing environment is called a master relation, under this input module. A generic relation of this type indicates aggregate levels of matching by the range of acceptance for each MOP defined. The by product master relations require the input of the range of values for each MOP for the possible levels of matching defined.

The SMP-DSS allows the definition of 12 different levels of matching. The matching levels names used for the case study are (modifiable though the structure module):

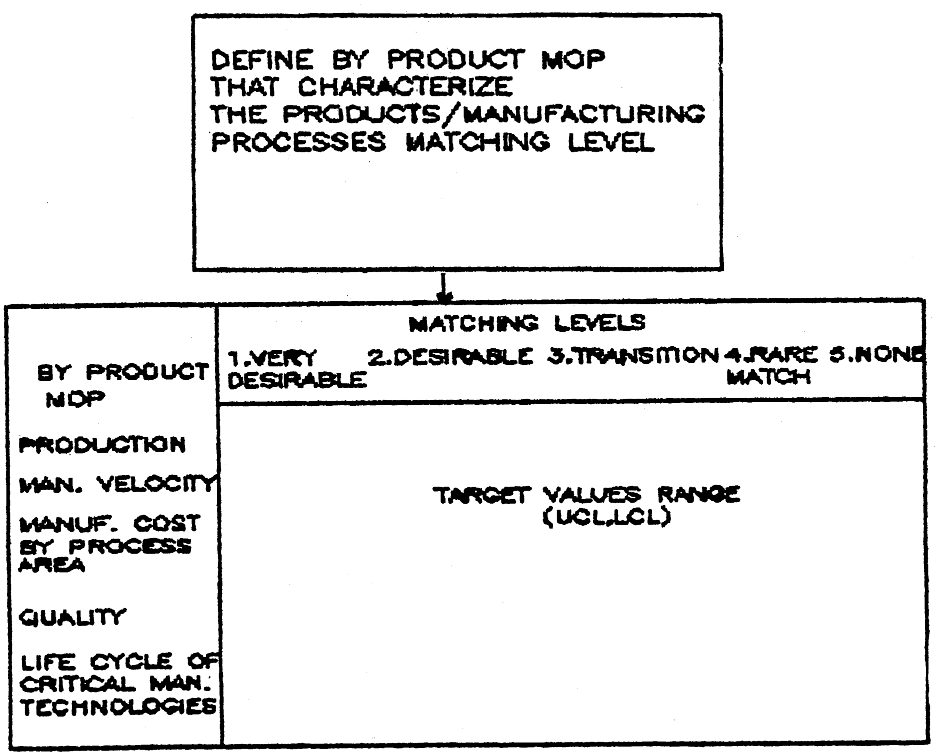
1) Very Desirable
2) Desirable
3) On transition
4) Rare match
5) No match
6) None

The definition of the generic and by product/process matching strategy according to the state of the system is performed in a way similar to the one in Figure 7.6.

Figure 7.8 is an example of these master relations. The system uses independent relations according to the state of the system.



a) Generic Product/Process Matching Strategy Master Relation.



b) By Product/Process Matching Strategy Master Relations

Figure 7.8. Master Relations (Product/Process Matching Strategy)

The weights associated to each MOP indicate the relative importance of the MOP in the evaluation of the product / process matching. Independent relations exist to define such weights according to the state of the system.

Appendix B, Section 2 contains the generic and by product/process matching strategy master relations used in the case example.

7.3.3 Economy Relations

The integration of economic factors into the SMP-DSS is extremely important, due to the fact that they could heavily influence the strategic decisions of a firm. Some economic factors affect industries in different ways. The firm must resolve which factors to consider, and establish the link between them and other relations of the system. The SMP-DSS has a specific set of economic factors defined as well as the links with other relations which are discussed in the evaluation sections.

The critical economic information common to most cases refers to: (current and projections)

a) industry segment contribution to the Gross Internal Product

b) inflation rate

c) money and capital market rates

- o prime rate
- o free risk rate

d) industry labor information

- o wages

o quality
o union climate

e) exchange rates

For the steel case study, the SMP-DSS considers the following input matrices:

A) Economy

1. Construction contribution to the gross internal product (Annual %)
2. Fabrication and manufacturing contribution to the gross internal product (Annual %)
3. Inflation rate (Mexico) (Annual %)
4. Inflation rate (U.S.A.)(Annual %)
5. Prime rate (Annual %)
6. Free risk rate (Annual %)
7. Industry weighted labor rate (pesos/day)
8. Labor market quality ranking (1-10=high)
9. Union climate ranking (1-10=controlled)
10. Exchange rate (pesos/dollar)
11. Oil price (pesos/Mexican barrel)

Appendix B, Section 3 has the detailed information.

B) GATT international steel prices projections of the firm products and new product lines.

7.3.4 Finance

This module defines the financial information of the firm and competitors. The financial information utilized in the system are the balance statement and the income statement. In both statements the information that is required is the highest level of aggregation needed up to the evaluation the major financial ratios discussed in Section 7.4.1.3.

The pro-forma statements appear as separate columns in the same matrix, as is shown in Appendix B, as present values adjusted for inflation discounted at K^* (Section 7.4.1.3). The system uses different relations for each state of the system.

The SMP-DSS works with the financial statements' concepts as follows:

A. Balance Statement (millions of pesos) (end of year) (1984-1993)

1. Inventories
2. Other current assets
3. Total current assets
4. Net fixed assets
5. Total Assets
6. Total current liabilities
7. Long term debt
8. Common stock
9. Retained earnings
10. Total net worth
11. Total claims on assets
12. Price of stock (thousands of pesos)
13. Dividend policy (% of net income)

B. Income Statement (1984 -1993)

1. Net sales
2. Cost of goods sold
3. Gross profit
4. Operating expenses
5. Gross operating income
6. Depreciation
7. Other income
8. Gross income
9. Interests
10. Net income before tax
11. Federal income tax
12. Net income after tax
13. Earnings per share (thousands of pesos)

The current and pro-forma statements are used in the calculation of critical financial ratios, which are then used in higher level relations of the system. The system allows the input of financial statements for the firm and three major competitors, assigning them to separate relations.

Appendix B, Section 4 shows modified information of the steel company.

7.3.5 Product(s)/Market(s)

The set of relations defined (Figure 7.9) in this module are:

1) Product characteristics and logistics definitions and specifications

2) Product characteristics and logistics weights

3) Demand of products and new products by firm

4) Concentration level by product

It is suggested first to define the following concepts: customer group, market, product type and industry segment to establish precisely the environment under consideration. This is important because the product lines defined in the system receive particular attention. The input information for each product line responds to the needs of the customer group linked to each product.

The demand of a firm's product and annual projections are considered to be a crucial input for the effectiveness of the evaluations performed by the system. The potential demand per product line is expected to change according to the customer's perception of how the firm's product satisfies requirements.

1) The values in the matrices of this module represent weighted averages of the market served. As was mentioned

in Chapter 5, a product performance profile is considered to examine product attributes or characteristics from the customer's viewpoint. The product characteristics to include should be kept to a minimum, just to assure that they are of value to the customer and strategically important to the company. Product characteristics that are strategically important to the company consist of specialized knowledge, patents, or other features vital for the good performance of the product.

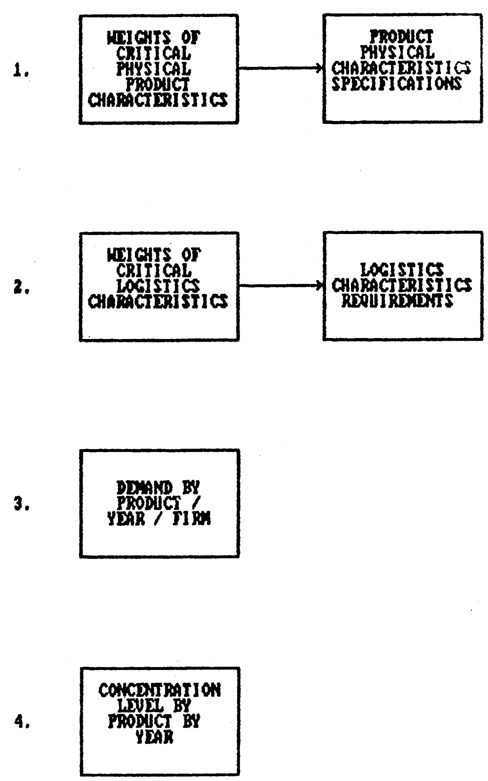


Figure 7.9. Product/Market Input Module Considerations

Two classes of characteristics are distinguished in the system:

1) Product intrinsic characteristics
2) Logistic's characteristics

The product intrinsic characteristics are physical attributes . For the steel company case, the critical characteristics included are: a) tensile strength (kg/cm^2), b) rolling strength (kg/cm^2), c) carbon contents (%), d) manganese contents (%), e) length (meters) and, f) surface quality (1-10=sharp, flow free, no pores, high quality).

Logistic's characteristics are performance measures from the customer's viewpoint on the effectiveness of the firm to meet its requirements. The example includes, a) Price (cost of product to customers, thousands of pesos/ton), b) Availability (average monthly safety stock, thousands of tons), c) Responsiveness (production by product by cycle, thousands of tons/cycle), d) Packaging (tons/package), e) Life cycle (stage of the product on life cycle curve), f) Performance (product performance ranking (1-10=excellent)), g) Social acceptance ranking (1-10=excellence).

The same approach is taken in the case of new products to define characteristics.

Upper and lower specifications for each characteristic by product are input in the corresponding relations.

2. The weight assigned to each characteristic, also from the customer's viewpoint is required to understand the major needs of the customer.

3. Past demand, prices and projections by product by firm are defined in this module.

4. The level of concentration by product type is expressed by the number of firms in the industry with sales volume greater than a specified value.

All this information is used in the evaluation of higher level relations which are the basis for the competitive advantage analysis and the consistency analysis modules. Appendix B, Section 5 has the detailed case information.

7.3.6 Supplier's Critical Information

Critical supplier's performance has to be taken into account in defining or evaluating the strategy of the firm. Firms usually have few vital materials which have to be traced with respect to quality, availability, cost and/or deliverability.

For the steel case presented, the actual concepts that the corporation follows closely are: (current and projections)

a) Extinction criticality (iron ore) (1-10=very critical)
b) Availability criticality (scrap) (1-10=very critical)
c) On time delivery (iron ore) (1-10=very critical)
d) On time delivery (scrap) (1-10=very critical)
e) Cost at site (iron ore) ($/ton)
f) Cost at site (scrap) ($/ton)
g) Cost of critical indirect materials (energy, $/KWH)
h) Cost of critical indirect materials (gas, $/cub.meters)
i) Cost of critical indirect materials (electrodes, $/Kg)
j) Cost of critical indirect materials (rollers, $/unit)

Such information is registered in this module. Similar relations exist for defining competitor's information. The detailed information is presented in Appendix B, Section 6.

7.3.7 Manufacturing

The strategic manufacturing considerations discussed in Chapter 5 are operationalized in the SMP-DSS. Due to the subjectivity of some factors, both objective measurable and subjective ranking criteria are expected in this module, as in other modules.

Two sets of input relations can be distinguished in this important module for the firm and each major competitor:

a) Product characteristics and logistics performance according to the state of the system

b) Manufacturing characteristics, capabilities and performance according to the state of the system

a) This group reflects aggregate product characteristics and logistics performance (Figure 7.10). This information represents the response of the firm to the market requirements. The actual product physical characteristics and logistics performance (state 1 of the system) of the manufacturing environment is drawn from the company's MPCS (Manufacturing Planning and Control System). The expected product physical characteristics and logistics performance (state 2) after doing changes to methods, product(s) design or process(es) is obtained through experts aided by modeling techniques. The same idea applies for the case of new products (state 3 of the system).

This module also contains the relations (Figure 7.11) with the results of the linear programming production model (external model) that is proposed in order to define the products and volume to manufacture by plant, referenced in Section 7.4.1.5.

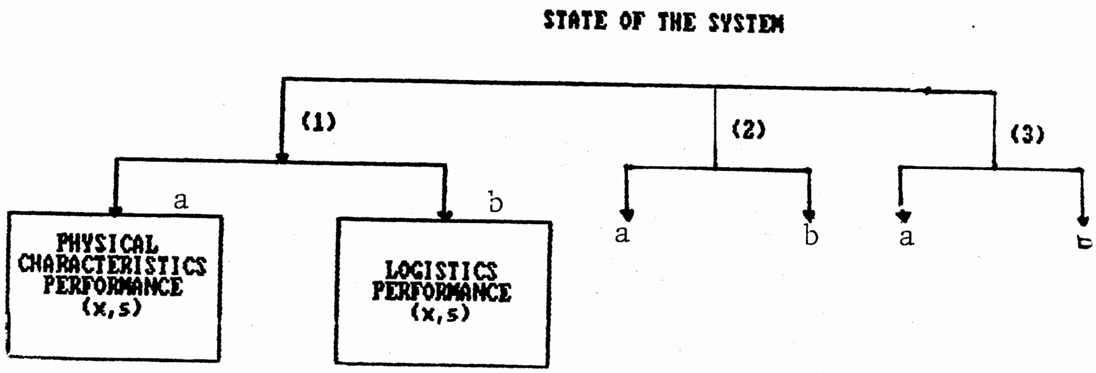


Figure 7.10. Product/Logistics Performance

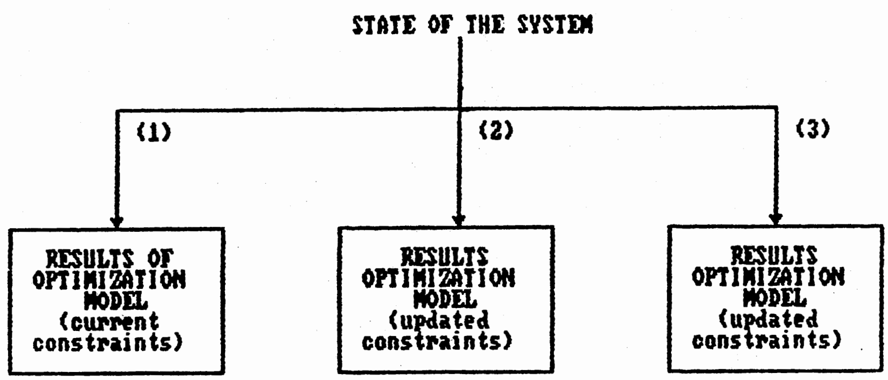


Figure 7.11. Results of Optimization Production Model

b) The second set of relations contains aggregate information of the manufacturing environment. The relation categories are the following:

1. Manufacturing characteristics
2. Processing times/product
3. Manufacturing/product degree of achievement
4. Production by product line/year
5. Capacity process area/year
6. Critical technologies life cycle status

7. Value added products/process
8. Yield/process area/product
9. Equipment utilization
10. Production/cycle
11. Batch size/product

Separate relations are included in the SMP-DSS for each state of the system for the firm and major competitors, shown in Appendix B Section 7. An explanation of each of the categories is described next.

1. The physical characteristics of the product selected are contrasted with each of the critical manufacturing technologies (reference Section 7.4.1.4), to obtain the degree to which technology j achieves physical characteristic i, expressed on a ranking scale (0-10). This information leads to the identification of the relative value of each characteristic for the firm in the achievement of new products (Section 7.4.1.4).

The manufacturing technologies that are included in the example are aggregate entities, processes or systems, like:

1. Reduction process-reactors
2. Continuous F.E. feeding system
3. Electric furnaces
4. Continuous casting machines
5. Reheating furnace
6. Rolling mill 15 stands
7. Rolling mill 8-2 block x stands
8. Spiral shaper/cooling uniform system
9. Overhead cranes/finishing area
10. Hercules lathes
11. Snider grinder
12. Chemical laboratory units
13. Physical laboratory units
14. Computer for electric furnace process control

2. The processing times by product are specified in this section. It is recommended to aggregate the information in

processing areas where the manufacturing value added/m^2 is low, (specified for each case). More detailed information should be consider for processing areas with high manufacturing value added/m^2 due to the fact that potential improvements are generally more valuable to the firm in such areas. The same idea applies for each of the three possible states of the system.

3. The different product lines of the firm are contrasted with each of the critical manufacturing technologies, to obtain the degree to which technology j achieves product i, expressed on a ranking scale (0-10). This information is used to obtain a relative measure of the value of each product in the achievement of new products (Section 7.4.1.4).

4. The actual and expected aggregate production by product line by year based on the state of the system is expected to be input in this module. This is vital partial information in the evaluation of higher matrices in the hierarchy. Thousand of tons is the unit used in the example.

5. The capacity by process area by year, based on a specified product mix, obtained through the use of a combination of optimization models and simulation, external aids of the SMP-DSS (explained in Section 7.4.1.5), is represented in the capacity relations in the input module. For the example presented in Appendix B, Section 7, the processing areas of the firm are: 1) reduction process, 2) furnace shop, 3) continuous casting machines, and 4) rolling

mill for the current analysis of the firm (state 1). The fundamental reasons to arrive at the definition of the elements to consider in states 2 and 3 for this firm are explained in the validation chapter. Thousands of tons is the capacity measure used in the example firm.

6. As was mentioned in Chapter 5, the manufacturing technology life cycle status is a critical determinant factor in the strategic positioning of the firm. Therefore, for the critical manufacturing technologies selected, its position on the life cycle matrix must be specified. Seven stage names are defined for these relations (the structure module allows them to be changed):

1) Development
2) Growth
3) Shakeout
4) Maturity
5) Saturation
6) Decline
7) Petrification

The life cycle position of a manufacturing technology is indicated with a "1" in the matrix.

7. The value added to a product by process area is defined as the total marginal costs added to a product by process area. As was mentioned in Chapter 5, the value added is an important element in the definition of the firm's strategy. The relations in Appendix B, Section 7, use the same process areas defined before and the unit of measure for the value added relations is thousands of pesos/ton. It is important to note, that this term is also used in

complementary terms, i.e., price minus total product costs.

8. Yield by process area reflects the fact of defective, waste or scrap material in between processes. The yield relations indicate the standard percentage of accepted product from one process to the next.

Figure 7.12 shows the input and output code materials by process, as a reference for the relations presented in Appendix B, Section 7.

9. The importance of aggregate process utilization factors varies according to the industry and the degree to which other measures of performance are weighted against utilization. It is less important as one moves towards more flexible manufacturing environments. For the steel firm case, utilization factors are weighted high on the master relations in the current assessment analysis, but decreased for states 2 and 3, due to the fact of the relative shift in strategy, as is shown in Chapter 8.

10. The aggregate production relations previously described contain annual information. The relations in this category require the input of the production and expected time per cycle. An optimization inventory model (external system) is used to dissaggregate the annual volume and obtain the required input information for these relations. For the specific example, the units used on these relations are, thousand of tons and days/cycle, and the information source is an optimization inventory model (Nuno, 1983).

11. This category of relations was designed to define

material flow factors, like batch sizes by product. For the specific example, tons/heat by product is the batch unit and is used in important calculations upstream, including manufacturing velocity, which is defined as the production rate per unit of time under no bottleneck and failure conditions.

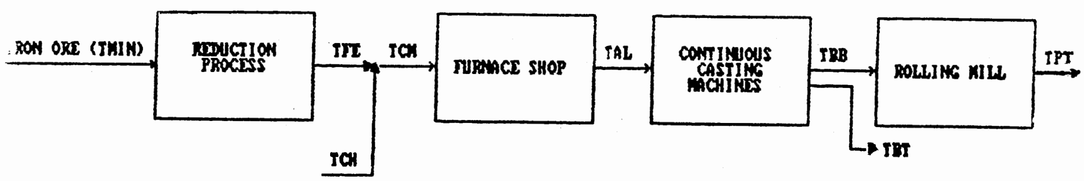


Figure 7.12. HYLSA's Major Processes

7.4 SMP-DSS Evaluation Modules

The evaluation modules of the SMP-DSS are divided in two major groups:

1) Internal evaluation

2) Environmental scanning

They are called evaluation modules because of the end-purpose of the system, the evaluation of the effect that manufacturing strategic decisions and selected environmental factors have on the business as a whole.

These are menu driven modules with a cascade of options that takes the user to the desired relation to evaluate. A direct access mode is also available. For each evaluation module, there is a corresponding output module that is described in Chapter 8.

7.4.1 Internal Evaluation

The internal evaluation modules of the firm are independent in the sense that all, one or more than one relation can be executed at a time, for flexibility purposes. However, if only selected relations are executed, the SMP-DSS assumes that the lower level relations that are not executed remain unchanged. As one gets involved with the system, it is easier to execute only the module(s) of interest, without the need of selecting the "evaluate all" option.

7.4.1.1 Generic Business Strategy and Manufacturing Strategy Consistency Evaluation. The generic and by product master relations described in Section 7.3.1, are used in the consistency analysis explained in this section. As was mentioned before, the master relations contrast measures of performance of different functional areas and environmental indicators with the set of generic strategies defined, establishing a range of acceptance for each pair (MOP, strategy) to define targets by strategy. This can be expressed as follows:

S_i = Generic strategy i(i=1,2,...,n).

n = Number of generic strategies defined.

a) Generic:

GW_j = Weight of generic measure of performance j.

$GUCL_{ij}$ = Upper limit of acceptance for strategy i, generic MOP j.

$GLCL_{ij}$ = Lower limit of acceptance for strategy i, generic MOP j.

b) By product:

PM_{lp} = Measure of performance l(l=1,2,...,L), product line p(p=1,2,...,P).

PW_{lp} = Weight of MOP l , product p.

$PUCL_{ilp}$ = Upper limit of acceptance for strategy i, MOP l, product p.

$PLCL_{ilp}$ = Lower limit of acceptance for strategy i, MOP l, product p.

The SMP-DSS evaluates the hierarchy of relations from which the MOP used in the analysis are extracted:

a) Generic:

GA_j = Generic MOP or indicator j after evaluation.

b) By product:

PA_{lp} = MOP or indicator l, product p after evaluation.

The function that evaluates consistency, extracts the strategy i with the highest weighted sum across the MOP or indicators conforming to the original master relations, expressed as follows:

- Generic:

$$AGS = MAX\ (\textstyle\sum_j GW_j Y_{1j},\ \sum_j GW_j Y_{2j}, \ldots,\ \sum_j GW_j\ Y_{nj}) \qquad [1]$$

where,

$$Y_{ij} = \begin{cases} 1, & GLCL_{ij} \le GA_j \le GUCL_{ij} \quad \text{for all } i \\ 0, & \text{otherwise} \end{cases}$$

where AGS is the generic strategy with the highest weighted sum of MOP conforming to the master relations.

The intended generic strategy s (IS_s)(s=1,2,...,n), defined in the input module, is compared to the one resulting (AGS) from the analysis [1].

- By product:

$$APS_p = MAX(\textstyle\sum_l PW_{lp}.X_{1l},\ \sum_l PW_{lp}.X_{2l}, \ldots, \sum_l PW_{lp}X_{nl}) \qquad [2]$$

where,

$$X_{il} = \begin{cases} 1, & PLCL_{ilp} \le PA_{lp} \le PUCL_{ilp} \quad \text{for all } i \\ 0, & \text{otherwise} \end{cases}$$

The intended by product strategy s (IPS_s) is compared to the one resulting (APS_p) from the analysis [2]. This could lead to specific strategic actions in the firm or modifications to the master relations as a result of the learning and research gained through the use of the SMP-DSS.

The APL functions of this module appear in Appendix F, Section 1.1.1.

<u>7.4.1.2</u> <u>Competitive</u> <u>Advantage</u> <u>Analysis.</u> The relative contribution of the firm's manufacturing strategy to the achievement of competitive advantage is assessed in this module. This is accomplished by performing analysis on specific MOP of the firms in the industry. This module complements the results of the previous one, in the sense that the consistency analysis results do not guarantee that a firm is achieving competitiveness on major market, financial or manufacturing issues. This module is an attempt to aid in such a task. Figure 7.13 presents a diagram of the general operation. The major MOP categories selected for the case example are: (Figure 7.13, block 2)

A) Finance aggregate business MOP
B) Aggregate manufacturing MOP
C) By product manufacturing MOP

The MOP considered in the example in this module represent important results for the firm. They are a sample and it is recommended to keep it small. The specific MOP by category in this specific module are: (Figure 7.13, block 3)

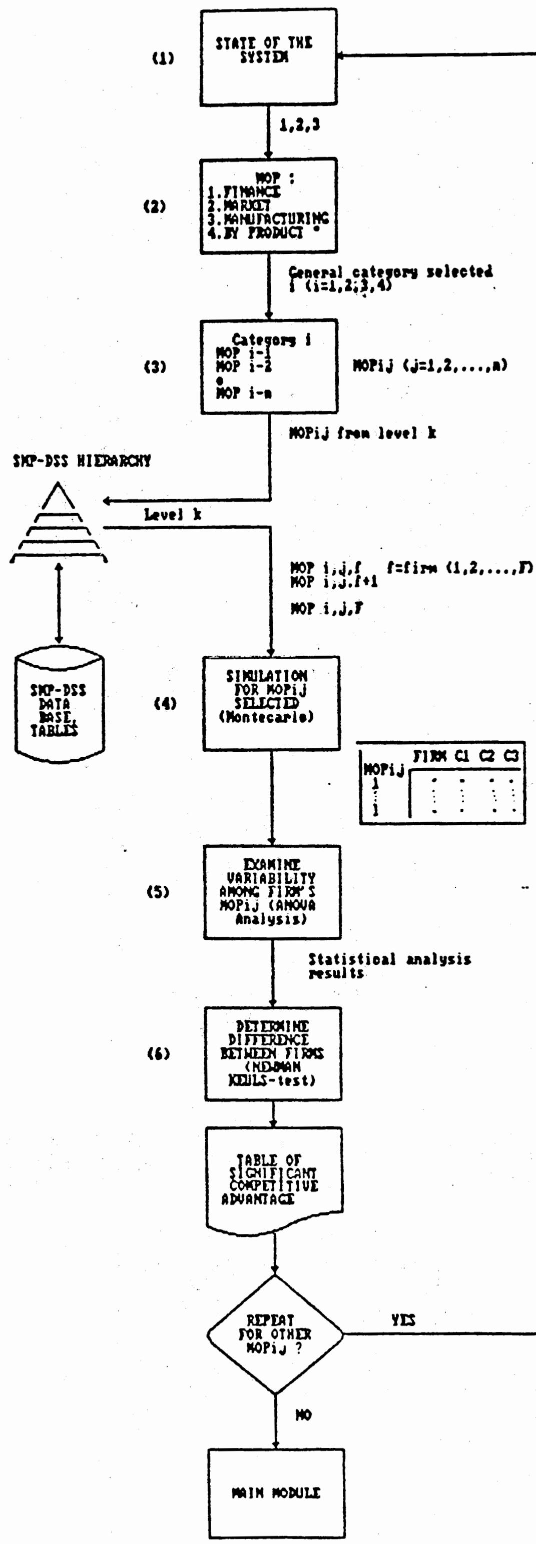


Figure 7.13. Diagram of the General Operation of the Competitive Advantage Analysis Module

A. Finance aggregate business MOP [b]
   1. Return on assets (%)
   2. Return on net worth (%)
   3. Inventory turns (times)
   4. Fixed assets turns (times)

B. Aggregate manufacturing [c]
   1. Weighted average manufacturing value added per ton per square meter ($/ton/square meter)
   2. Weighted average manufacturing velocity (tons/minute)
   3. Weighted average yield (TAL/TCM (%))
   4. Flexibility index (index)
   5. Utilization of electric furnaces (%)
   6. Utilization of rolling mill (%)

C. By product line manufacturing [c]
   1. Manufacturing value added per ton per square meter ($/ton/square meter)
   2. Manufacturing velocity (tons/minute)
   3. Yield (TAL/TCM (%))
   4. Market satisfaction on tensile strength (%)
   5. Market satisfaction on carbon (%)
   6. Market satisfaction on manganese (%)
   7. Responsiveness (tons/cycle)
   8. Flexibility index (index)

The test of the hypothesis that no difference exist between firms (H_o) based on the MOP selected is the end purpose of this module.

It is recommended that the MOP used in this module be defined in such a way that greater values mean better performance for a specific MOP. This assures uniform interpretation of the output table results.

The Monte Carlo simulation (Figure 7.13, block 4) generates random samples for the MOP_{ij} selected. This is performed for the firm and major competitors. The SMP-DSS

[b] For definitions, see section 7.4.1.3
[c] Definitions are given in the module where they are calculated.

generates normal samples using the MOP_{ij} value extracted from the hierarchy of relations as the mean and a percentage of the mean as the standard deviation (20% for the example). The generation routine appears in Appendix F, Section 1.1.2.

The sampled observations are then reviewed using the F test in a one-way analysis of variance, in which k populations each representing one level of treatment (firms), can be considered with observations Y_{ij} as shown in Table 7.1 (Figure 7.13, block 5).

TABLE 7.1

POPULATION LAYOUT FOR ONE-WAY ANOVA

	Treatment					
	1	2	···	j	···	k
	Y_{11}	Y_{12}		Y_{1j}		Y_{1k}
	Y_{21}	Y_{22}		Y_{2j}		Y_{2k}
	Y_{31}	Y_{32}		—		—
	—	—		—		—
	Y_{i1}	Y_{i2}		Y_{ij}		Y_{ik}
Population means	$\mu_{.1}$	$\mu_{.2}$	···	$\mu_{.j}$	···	$\mu_{.k}$

Here the use of the "dot notation" indicates a summing over all observations in the population. The treatment effect, t_j , can also be indicated by $u_{.j} - u$, and then the model is either

$$Y_{ij} = u + t_j + e_{ij}$$

or

$$Y_{ij} - u = (u_{.j} - u) + (Y_{ij} - u_{.j})$$

From the random samples drawn from each population, estimates can be made of the treatment means and the grand mean. If n_j observations are taken for each treatment where the numbers need not be equal, a sample layout would be as shown in Table 7.2.

TABLE 7.2

SAMPLE LAYOUT OF THE RESULTING ANOVA IN THE SMP-DSS

	Treatment						
	1	2	...	j	...	k	
	Y_{11}	Y_{12}	...	Y_{1j}	...	Y_{1k}	
	Y_{21}	Y_{22}	...	Y_{2j}	...	Y_{2k}	
	⋮	⋮		⋮		⋮	
	Y_{i1}	Y_{i2}	...	Y_{ij}		Y_{ik}	
	⋮	⋮		⋮		⋮	
	$Y_{n_1 1}$	⋮		$Y_{n_j j}$		⋮	
		$Y_{n_2 2}$				$Y_{n_k k}$	
Totals	$T_{.1}$	$T_{.2}$	...	$T_{.j}$	...	$T_{.k}$	$T_{..}$
Number	n_1	n_2	...	n_j	...	n_k	N
Means	$\bar{Y}_{.1}$	$\bar{Y}_{.2}$	...	$\bar{Y}_{.j}$	...	$\bar{Y}_{.k}$	$\bar{Y}_{..}$

Here $T_{.j}$ represents the total of the observations taken under treatment j, n_j represents the number of observations taken for firm j, and $\bar{Y}_{.j}$ is the observed mean for firm j. $T_{..}$ represents the grand total of all observations taken where

$$T_{..} = \sum_{j=1}^{k} \sum_{i=1}^{n_j} Y_{ij} = \sum_{j=1}^{k} T_{.j}$$

and

$$N = \sum_{j=1}^{k} n_j$$

and $\bar{Y}_{..}$ is the mean of all N observations.

$$\bar{Y}_{..} = \sum_{j=1}^{k} n_j Y_{.j} \; / \; N$$

The test of the hypothesis can be made using the F distribution with the observed F at k-1 and N-k degrees of freedom given by (Hicks, 1973):

$$F_{k-1,N-k} = \frac{\sum_{j=1}^{k} n_j \; (Y_{.j} - \bar{Y}_{..})^2 / (k - 1)}{\sum_{j=1}^{k} \sum_{i=1}^{n_j} \; (Y_{ij} - \bar{Y}_{.j})^2 / (N - k)}$$

The critical region is usually taken as the upper tail of the F distribution, rejecting H_o if $F > F_{1-\alpha}$ where α is the area above $F_{1-\alpha}$. In this F ratio, the sum of squares between treatments is always put into the numerator, and then a significant F will indicate that the differences between means has something in it besides the estimate of variance. It probably indicates that there is a real difference in the firm's MOP means ($u_{.1}, u_{.2}, \ldots$) and that H_o (no competitive advantage based on such MOP_{ij}) should be rejected.

A detailed description of ANOVA tests is given by Hicks, 1973. The formulas for the one-way ANOVA test used in the system are summarized in Table 7.3,
where,

- k = number of firms
- N = total number of observations
- Y_{ij} = observation values
- $\bar{Y}$ = mean values

TABLA 7.3

ONE WAY ANOVA

Source	df	SS	MS
Between treatments τ_j	$k-1$	$\sum_{j=1}^{k} n_j(\bar{Y}_{.j}-\bar{Y}_{..})^2 = \sum_{j=1}^{k} \frac{T_{.j}^2}{n_j} - \frac{T_{..}^2}{N}$	$SS_{treatment}/(k-1)$
Within treatments or error ε_{ij}	$N-k$	$\sum_{j=1}^{k}\sum_{i=1}^{n_j}(Y_{ij}-\bar{Y}_{.j})^2 = \sum_{j=1}^{k}\sum_{i=1}^{n_j} Y_{ij}^2 - \sum_{j=1}^{k}\frac{T_{.j}^2}{n_j}$	$SS_{error}/(N-k)$
Totals	$N-1$	$\sum_{j=1}^{k}\sum_{i=1}^{n_j}(Y_{ij}-\bar{Y}_{..})^2 = \sum_{j=1}^{k}\sum_{i=1}^{n_j} Y_{ij}^2 - \frac{T_{..}^2}{N}$	

The results of the analysis of variance are then used to examine the difference between firms, to determine statistically if competitive advantage exists or not between firms based on the MOP_{ij} chosen. A summary of the Newman-Keuls range test used to accomplish such a task is described next.

1. Arrange the k means in order from low to high.
2. Enter the ANOVA table and take the error mean square with its degrees of freedom.
3. Obtain the standard error of the mean for each treatment

$$S_{\bar{Y}_{.j}} = \sqrt{\frac{\text{error mean square}}{\text{number of observations in } \bar{Y}_{.j}}}$$

   where the error mean square is the one used as the denominator in the F test on means $\bar{Y}_{.j}$.

4. Enter a Studentized range table of significant ranges at the level desired, using (N-k) degrees of

freedom and p=2,3,...,k, and list these k-1 ranges.

5. Multiply these ranges by $S_{\bar{y}_{.j}}$ to form a group of k-1 least significant ranges.

6. Test the observed ranges between means, beginning with largest versus smallest, which is compared with the least significant range for p=k; then test largest versus second smallest with the least significant range for p=k-1; and so on. Continue this for second largest versus smallest, and so forth, until all k(k-1)/2 possible pairs have been tested. The sole exception to this rule is that no difference between two means can be declared significant if the two means concerned are both contained in a subset with a nonsignificant range.

The evaluation functions of this module are listed in Appendix F, Section 1.1.2.

<u>7.4.1.3</u> <u>Financial</u> <u>Evaluation</u>. The presentation is divided into two parts:

1) Financial ratios and trends analysis

2) Cash flows impact adjustments on pro-forma statements

1) The economic impact of any change to the relations of the SMP-DSS has to be reflected on the financial statements of the firm. These are used in the calculation of important financial ratios and trends by year described next, which are critical measures of performance used in the competitive advantage analysis and in the consistency analysis. For a detailed discussion of managerial financial issues, see (Weston, 1985).

A. Basic Type of Financial Ratios. It is useful to classify the financial ratios considered in the SMP-DSS into four fundamental types:

a. Liquidity ratios, which measure the firm's ability to meet its maturing short-term obligations.

b. Leverage ratios, which measure the extent to which the firm has been financed by debt.

c. Activity ratios, which measure how effectively the firm is using its resources.

d. Profitability ratios, which measure management's overall effectiveness as shown by the returns generated on sales and investment.

a. Liquidity.

- Current Ratio. The current ratio is computed by dividing current assets by current liabilities. Current assets normally include cash, marketable securities, accounts receivable, and inventories; current liabilities consist of accounts payable, short-term notes payable, current maturities of long-term debt, accrued income taxes, and other expenses (principally wages). The current ratio is the most commonly used measure of short-term solvency, since it indicates the extent to which the claims of short-term creditors are covered by assets that are expected to be converted to cash in a period roughly corresponding to the maturity of the claims.

$$\text{Current ratio} = \frac{\text{current assets}}{\text{current liabilities}}$$

- Quick Ratio (acid test). The quick ratio is obtained by deducting inventories from current assets and dividing the remainder by current liabilities. Inventories are typically the least liquid of a firm's current assets and the assets on which losses are most likely to occur in the event of liquidation. Therefore, this measure of the firm's ability to pay off short-term obligations without relying on the sale of inventories is important.

$$\text{Quick ratio} = \frac{\text{current assets - inventory}}{\text{current liabilities}}$$

b. Leverage Ratios. Leverage ratios measure the funds supplied by owners as compared with the financing provided by the firm's creditors. In practice, leverage is approached in two ways. One approach examines balance sheet ratios and determines the extent to which borrowed funds have been used to finance the firm. The other approach measures the risks of debt by income statement ratios designed to determine the number of times fixed charges are covered by operating profits. These sets of ratios are complementary, and most analysts examine both leverage ratios.

The ratio of total debt to total assets, generally called the debt ratio, measures the percentange of total funds provided by creditors. Debt includes current liabilities and all bonds. Creditors prefer moderate debt ratios, since the lower the ratio, the greater the cushion against creditors' losses in the event of liquidation. In constrast to the creditors' preference for a low debt ratio, the owners may seek high leverage either (1) to magnify earnings or (2) because raising new equity means giving up some degree of control.

$$\text{Debt ratio} = \frac{\text{total debt}}{\text{total assets}} \quad (\%)$$

c. Activity ratios. These ratios all involve comparisons between the level of sales and the investment in various assets accounts.

- Inventory turnover. The inventory turnover is defined as sales divided by inventories.

$$\text{Inventory turnover} = \frac{\text{sales}}{\text{inventory}} \quad \text{(turns per year)}$$

Two problems arise in calculating and analyzing the inventory turnover ratio. First, sales are at market prices; if inventories are carried at cost, as they generally are, it would be more appropriate to use cost of goods sold in place of sales in the numerator of the formula. The second problem lies in the fact that sales occur over the entire year, whereas the inventory figure is for one point in time. Therefore, the average inventory over the year should be used instead.

- Fixed Assets Turnover. The ratio of sales to fixed assets measures the turnover of plant and equipment.

$$\text{Fixed assets turnover} = \frac{\text{sales}}{\text{net fixed assets}} \quad \text{(turns per year)}$$

- Total Assets Turnover. It measures the turnover of all the firm's assets - it is calculated by dividing sales by total assets.

$$\text{Total Assets Turnover} = \frac{\text{sales}}{\text{total assets}} \quad \text{(turns per year)}$$

d. Profitabiliby Ratios. Profitability is the net result of a large number of policies and decisions. The ratios examined thus far reveal some interesting things about the way the firm is operating, but the profitability ratios give final answers about how effectively the firm is being managed.

- Profit Margin on Sales. The profit margin on sales, computed by dividing net income after taxes by sales, gives the profit per dollar of sales.

$$\text{Profit margin} = \frac{\text{net profit after taxes}}{\text{sales}} \quad (\%)$$

- Return on Total Assets. The ratio of net profit to total assets measures the return on total investment in the firm.

$$\text{Return on total assets} = \frac{\text{net profit after taxes}}{\text{total assets}} \quad (\%)$$

- Return on Net Worth. The ratio of net profit after taxes to net worth measures the rate of return on the stockholders' investment.

$$\text{Return on net worth} = \frac{\text{net profit after taxes}}{\text{net worth}} \quad (\%)$$

B. Trend Analysis. While the preceding ratio analyses give a reasonably good picture of the "health" of a firm, it is incomplete in one important respect; it ignores the time dimension. The ratios are snapshots of the picture at one point in time , but there may be trends in motion that are in the process of rapidly eroding a relatively good present position. Converselely, an analysis of the ratios over the past few years may suggest that a relatively weak position is being improved at a rapid rate.

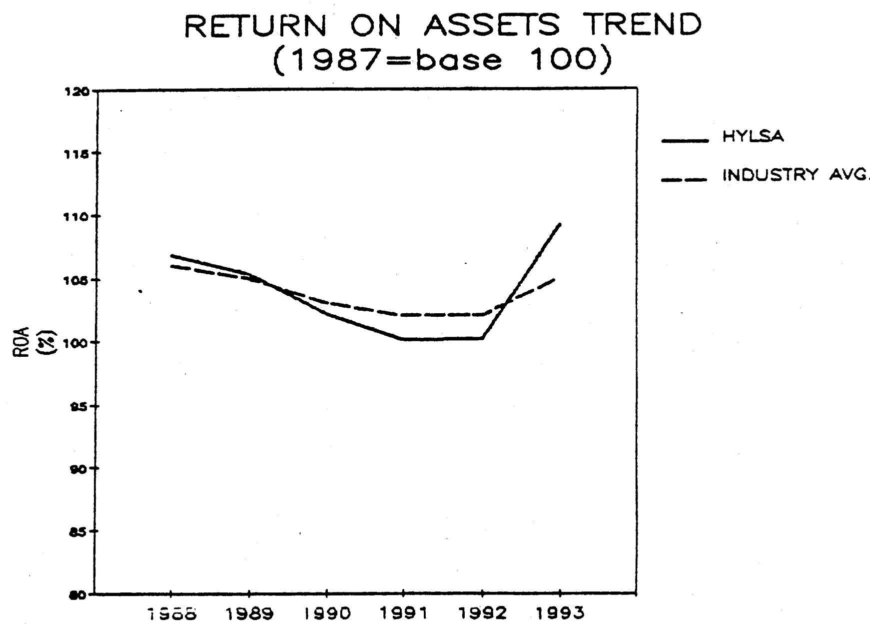


Figure 7.14. Illustration of Trend Analysis

The method of trend analysis is illustrated in Figure 7.14, which shows the trend expected for return on assets for the steel firm. The figures are compared with industry averages. The same conceptual logic applies for the calculation of ratios and trends for the firm and competitors.

2) The economic impact of any change to the relations of the system, mentioned at the beginning of this section, has to be reflected on the pro-forma financial statements provided by the SMP-DSS. The way the system handles this situation is described next. First, the cash flow matrix mentioned in Section 7.2.3 containing the "now" dollars cash flows by year is adjusted for inflation.

These cash flows represent the economic evaluation results of the strategic projects listed on the same matrix. Then, these cash flows are discounted to present values at rate K^*_i per year,

$$K^*_i = (1 + f_i)\ (1 + K_i)$$

where f_i = inflation rate end of year i (annual %)

K_i = minimum attractive rate of return (annual %), or cost of capital to the firm for year i.

The resulting cash flows by year are then presented to the user to make the appropriate adjustments to the pro-forma balance and income statements by year. The diagram of the operation is presented in Figure 7.15.

The APL functions corresponding to this section appear in Appendix F, Section 1.1.3.

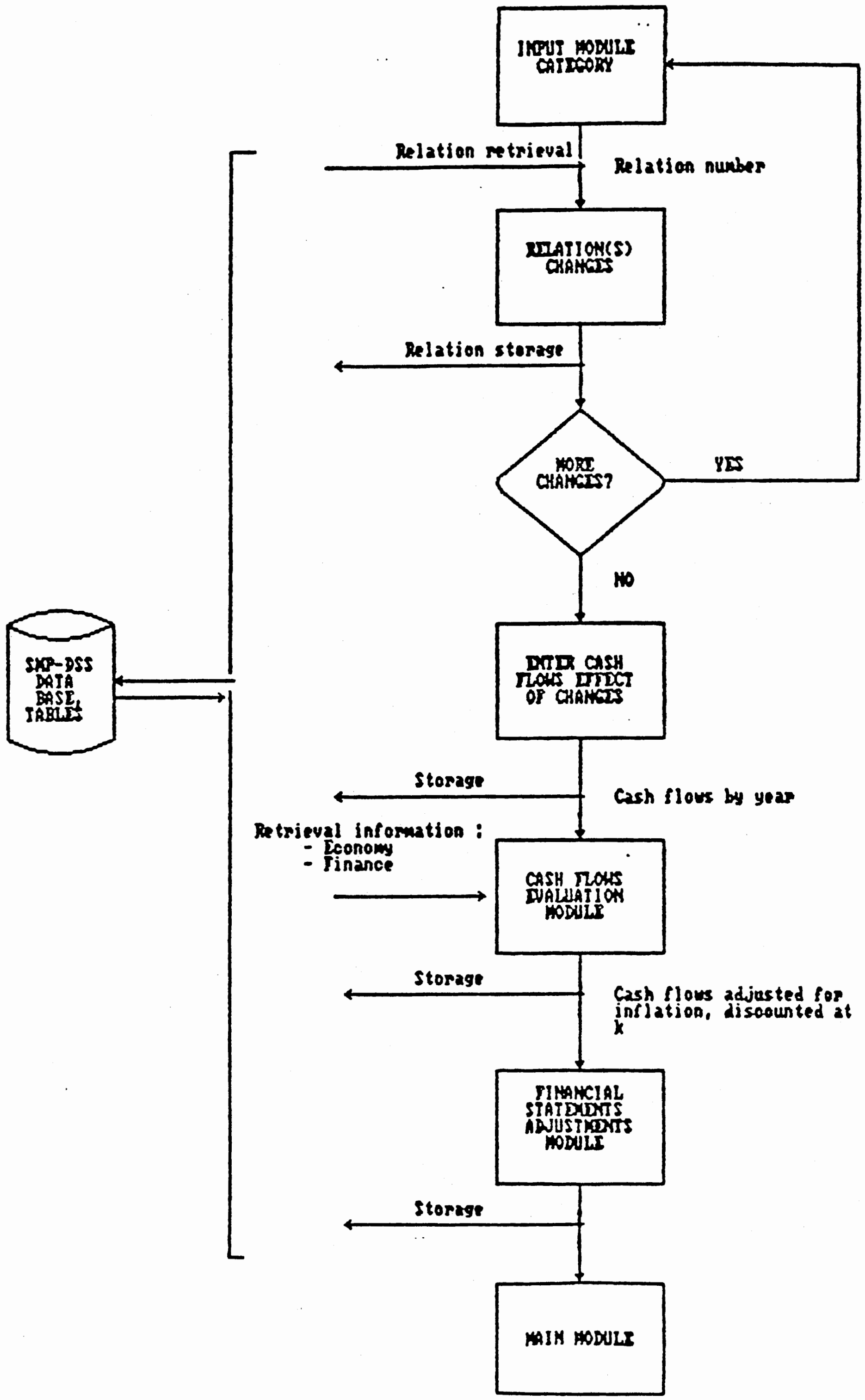


Figure 7.15. Diagram of the Cash Flows Treatment by the SMP-DSS

7.4.1.4 Product/Process Matching Strategy Evaluation. There are two major evaluation groups in this module:

A) The generic and by product/process matching strategy evaluation

B) Flexibility evaluation

It can be said that CIM alters the determinants of the intensity of competition in a given market: a firm investing in such integrated systems may have an effect on the availability of market substitutes and on the power of buyers (output flexibility), and, an effect on entry barriers and power of suppliers (input flexibility). Competitive rivalry also changes as CIM gives to the firm a better way to counteract threatening moves by competitors by reducing retaliation lags (process flexibility) and as it devises defensive or offensive actions either by better positioning in the face of the prevailing competitive forces or by influencing these forces, with the required degree of overall system flexibility.

Because the core technology is better in tune with its environment, strategies exploiting changes in the product market can become more effective (especially for diversification or market entry purposes). A particular environment where it seems appropriate to use flexible manufacturing systems and other technologies is in fragmented industries. Fragmented industries are industrial settings where each firm has no significant share of the market, yet each of them has the power to influence industry outcomes.

Such environments are characterized by factors such as diverse product line, diverse market needs and high product differentiation. Accordingly, firms cope with fragmentation with classical responses like decentralized structures, or specialization by product type, customer type, or geographical area. These firms don't have a high market share because of the presence of diseconomies of scale typical of such an environment. FMS and CIM technologies could add to the set of possible competitive moves by creating potential for high-variety, low volume goods.

A) The generic and by product/process master relations described in Section 7.3.2 are used here. This module evaluates the actual or expected results of the match between the product line and its manufacturing environment. From Section 7.3.2, the different relations described can be expressed as follows:

L_i = Matching level i(i=1, 2,...,n).

n = Number of levels defined.

For the generic matching evaluation:

GLM_j = Generic measure of performance j (j=1,2,...,JJ).

GLW_j = Weight of generic measure of performance j.

$GLUC_{ij}$ = Upper control limit for matching level i, generic MOP j.

$GLLC_{ij}$ = Lower control limit for matching level i, generic MOP j.

For the by product/process matching evaluation:

PLM_{lp} = Measure of performance l (l=1,2,...,LL), product line p (p=1,2,...,P).

PLW_{lp} = Weight of MOP l, product p.

$PLUC_{ilp}$ = Upper control limit for matching level i, MOP l, product p.

$PLLC_{ilp}$ = Lower control limit for matching level i, MOP l, product p.

After calculating the hierarchy of relations, the MOP are extracted from the corresponding matrices, resulting in two classes:

1) Generic

GLA_j = Generic MOP j

2) By Product

PLA_{lp} = MOP l, product p

The function that evaluates matching, extracts the level of matching i with the highest weighted sum across the MOP conforming to the original master relations, that is

1) Generic

$$AGL = MAX\left(\sum_j GLW_j\, Z_{1j},\ \sum_j GLW_j\, Z_{2j}\ ,\ldots,\ \sum_j GLW_j\, Z_{nj}\right)$$

where,

$$Z_{ij} = \begin{cases} 1, & GLLC_{ij} \le GLA_j \le GLUC_{ij} \quad \text{for all } i \\ 0, & \text{otherwise} \end{cases}$$

where AGL is the level of matching achieved.

The expected generic level of matching t (IL_t) (t=1,2,..., n) defined in the input module, is compared to the one resulting (AGL) from the analysis. This provides a general measure of the level of matching as a function of the product/process requirements expressed in terms of performance.

2) By product

$$APL_p = MAX\ (\sum_l PLW_{lp}\ V_{1l},\ \sum_l PLW_{lp}\ V_{2l}, \ldots, \sum_l PLW_{lp} V_{nl})$$

where,

$$V_{il} = \begin{cases} 1, & PLLC_{ilp} \le PLA_{lp} \le PLUC_{ilp} \quad \text{for all } i \\ 0, & \text{otherwise} \end{cases}$$

The by product/process matching expected t (IPL_t) is compared to the resulting (APL_p) from the analysis. This provides a way to define strategic moves from where the firm stands based on the results of the analysis. The strategic implications of the position or changes in the product/process matrix are given in general in Chapter 5. Appendix F, Section 1.1.4 has the functions of this module.

B) Flexibility Evaluation. The concept of flexibility is being used at different levels and for different purposes (Kumar 1987). Flexibility is defined here as the relative contribution of the firm's current product line or product's characteristics and manufacturing technologies to the achievement of new products. It is a MOP used in master relations and its relative importance against other MOP depends on the strategy and the industry in question. A conceptual model (Hanieski, 1984), was extended and adapted as a flexibility measuring model in the SMP-DSS. A description of the model is explained next.

The central explanatory device of this model depends upon the vector of physical characteristics associated with the products. A final product may be described by a vector of physical properties.

The characteristic-technology transfer matrix $A = (a_{ij})$ defined in Section 7.3.7 is normalized to obtain values between (0,1).

For example, suppose the firm produces a product with characteristics m_1, m_2, m_3, which involve technologies T_1, T_2, T_3, T_4, as

m_1 : T_1, T_2
m2 : T_2, T_3, T_4
m_3 : T_1, T_3

	T_1	T_2	T_3	T_4
m_1	1	1	0	0
m_2	0	1	1	1
m_3	1	0	1	0

An entry in the i^{th} row and j^{th} column denotes the contribution to the firm's knowledge of the j^{th} technology from achieving the i^{th} characteristic.

The technology new product transfer matrix is defined as:

$$B = (b_{jp})$$

where (b_{jp}=1,2,...,10) and represents the degree to which manufacturing technology j contributes to new product p. The values are then normalized.

For example, suppose the firm has knowledge of four technologies T_1, T_2, T_3, T_4 by implementing characteristics m_1, m_2, m_3 and these technologies contribute to the extension of the firm's product line to products P_1, P_2, P_3, as

$$T_1 \rightarrow P_1$$
$$T_2 \rightarrow P_2, P_3$$
$$T_3 \rightarrow P_1, P_3$$
$$T_4 \rightarrow P_1, P_2, P_3$$

The transfer matrix B is defined as:

$$B = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Element $b_{j,p}$ is interpreted as the relative contribution technology j makes to the introduction of new product p to the firm's line.

The characteristic-new product contribution can be calculated as follows. Suppose achieving characteristic i adds to the firm's knowledge of technology j which is necessary to develop new product p. The complete link is

$$m_i \rightarrow T_j \rightarrow P_p$$

and can be calculated as

$$a_{ij}\ b_{jp}$$

If the complete link does not exist,

$$a_{ij}\ b_{jp} = 0$$

A relative measure of the way characteristic i contributes to new product p is,

$$\sum_j a_{ij} b_{jp}$$

Let

$$c_{ip} = a_{ij} b_{jp}$$

then c_{ip} is the number of ways m_i is contributing to P_p.

Let

$$C = (c_{ip})$$

then,

$$C = AB$$

For example, having

characteristics m_1, m_2, m_3

technologies T_1, T_2, T_3, T_4

new products P_1, P_2, P_3.

With A and B as in the previous examples,

$$AB = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 2 & 2 & 3 \\ 2 & 0 & 1 \end{bmatrix} = C$$

C is interpreteted as:

m_1 contributes to each new product in one way;

m_2 contributes to P_1 and P_2 in two ways each and three ways to new product 3;

m_3 contributes two ways to P_1, no ways to P_2, and one way to P_3.

A new product value model can be constructed associating an expected value to the firm for each of the new products.

$$v_p \rightarrow P_p$$

where, v_p = Marginal contribution of new product p (selling price_p - variable costs_p)

These values may be normalized such that

$$\sum_p v_p = 1$$

Now consider a characteristic i that contributes to new product p in c_{ip} ways. The value of extending m_i , relative to P_p , is given by

$$c_{ip}\, v_{m_i p}$$

The total value of m_i is given by the weighted sum

$$v_i = \sum_p c_{ip}\, v_p$$

For example, suppose the relative values of each of the new products is given by V = (1/6, 1/3, 1/2).

The value of each characteristic in achieving a new product is

$$CV = \begin{bmatrix} 1 & 1 & 1 \\ 2 & 2 & 3 \\ 2 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1/6 \\ 1/3 \\ 1/2 \end{bmatrix} = \begin{bmatrix} 1 \\ 2\ 1/2 \\ 5/6 \end{bmatrix} = v_i .$$

The column vector v_i , where i=1, 2, 3, is interpreted as:

- characteristic 1 (m_1) has a relative value to the firm, with respect to the three potential new products, of 1;
- characteristic 2 (m_2) has a relative value to the firm, with respect to the three potential new products, of 2.5
- characteristic 3 (m_3) has a relative value to the firm of 5/6.

This means that effort on activities aimed at optimizing m_2 is two and a half times as beneficial to the firm as activity on m_1; it is three times better than m_3.

The relative value of each characteristic is computed from the number of technologies that it instructs the firm in, the number of ways those technologies can be used, and the relative values of those uses. The column vector V denotes those relative values and the elements represent information gained by the marketing research department about the demand conditions for the new product, the degree of competition the firm would meet in marketing the new product, the similarity to the marketing arrangements the firm already has in marketing its existing products, etc.

This analysis implies that there are products which are much more powerful in adding to a firm's (country's, individual's) technological base than would at first be suspected. The only change required in the analysis is to redefine m_i as product i instead of characteristic i.

The analysis offers a simplified approach to the problem of technology assessment. It does not rely solely on a demand-pull approach, nor does it evaluate R & D projects without regard to possible extensions of the firm's product line. It provides a framework for analyzing the aspects of technological change as a system of interacting elements.

The APL functions that represent this model are found in Appendix F, Section 1.1.4.

7.4.1.5 Aggregate Demand/Supply Capacity Evaluation. The firm's actual market share, denoted by S_k, is compared with its structural potential market M_k, to identify the nature of measures that must be taken to improve the competitive position of the firm. The necessary strategic measures in this respect can be classified into two groups: measures aimed at (1) increasing the actual market share S_k when $S_k \leq M_k$ and (2) increasing the structural market share M_k when $M_k \leq S_k$ The first case $S_k \leq M_k$ implies that the firm has the potential to sell more than it actually does and therefore it must take some managerial and marketing measures to exploit the existing favorable competitive strength it possesses. The second case $M_k \leq S_k$, on the other hand, implies that the firm is actually exploiting the market more than its competitive strength indicates. This is rather a vulnerable position to be in since the awareness of the situation by the competitors may change the rules of the game.

Two different approaches are considered in the SMP-DSS for this module reflecting the following capacity assumptions:

1) Infinite loading (no resources restrictions)

2) Finite loading (resources restrictions)

1. The SMP-DSS evaluation functions first calculate the difference between the current and expected demand and supply by year, by end product, by firm to determine the surplus or shortage of units of end products by firm. The resulting relation by firm is then used to calculate the total capacity

required (in tons for the steel industry case) by process by year to match the demand by product by year. Figure 7.16 illustrates the operation under this assumption.

2. For the case of finite loading, it is proposed to have external modeling aids represented in Figure 7.17, to aid in the critical decision of products to manufacture and their corresponding volume per year.

Most of the SMP-DSS manufacturing input relations of this module are supported by the models in Figure 7.17 for the steel firm HYLSA (Nuño, 1983). The specific models are not discussed here. The optimization model suggested is of the form:

Objective: Maximize total annual marginal contribution over all products.

Subject to:

1) Demand constraints by zone
2) Capacity constraints
3) Technological constraints
4) Maintenance constraints

The firms in this K-firm industry have different factor productivities stemming from differences in manufacturing processes, managerial skills, variations in production input quality, and environmental conditions. Also assumed is that, in order to avoid the usual definitional problem between "market" and "industry", each member firm produces the same set of products, each of which is related on the input side, as in the case of iron and steel. The quantity to be produced of product p within a planning period is a decision variable for firm k. The firm attempts to determine the optimal values

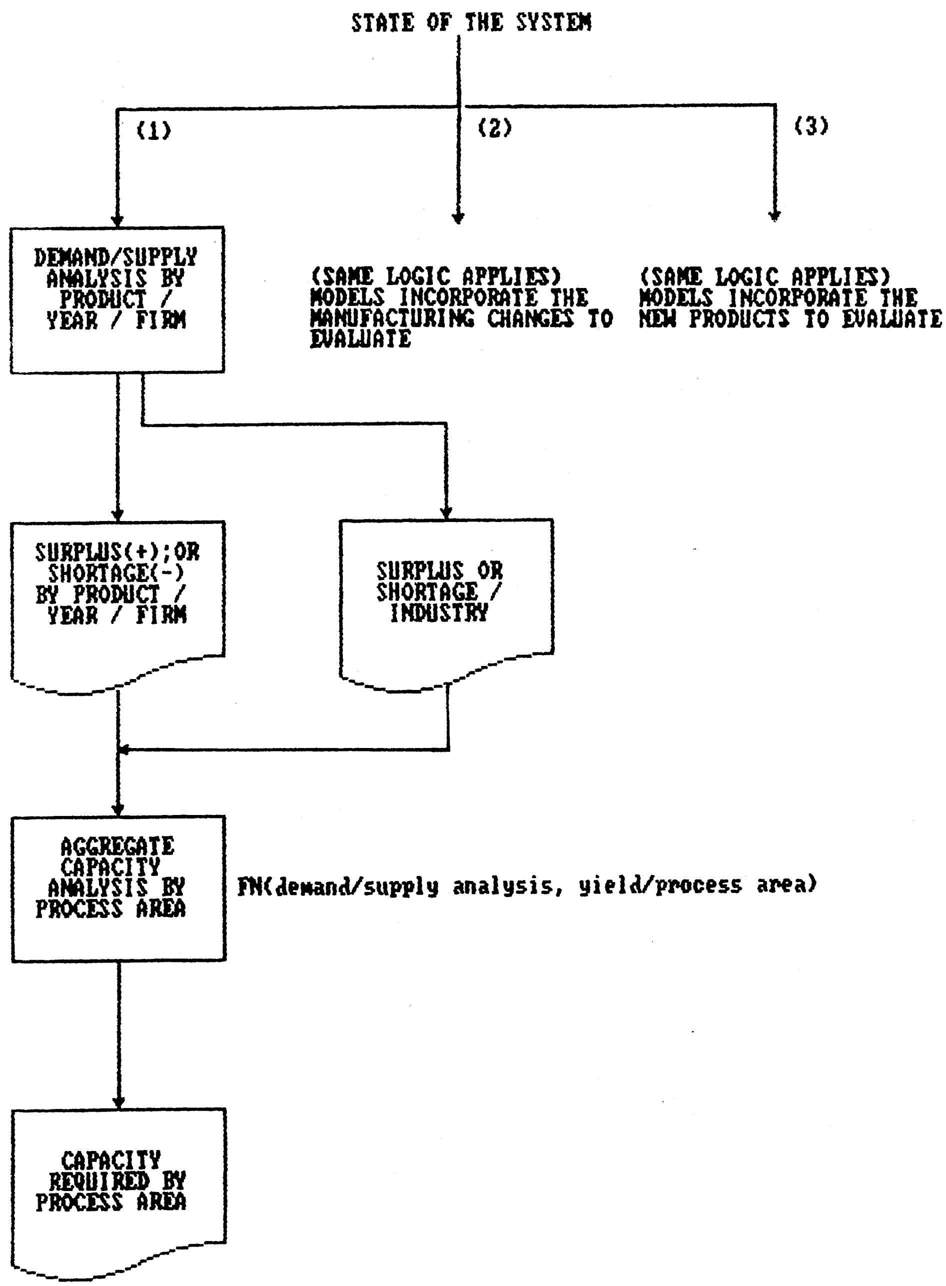


Figure 7.16. Demand/Supply-Capacity Evaluation (Infinite Loading Assumption)

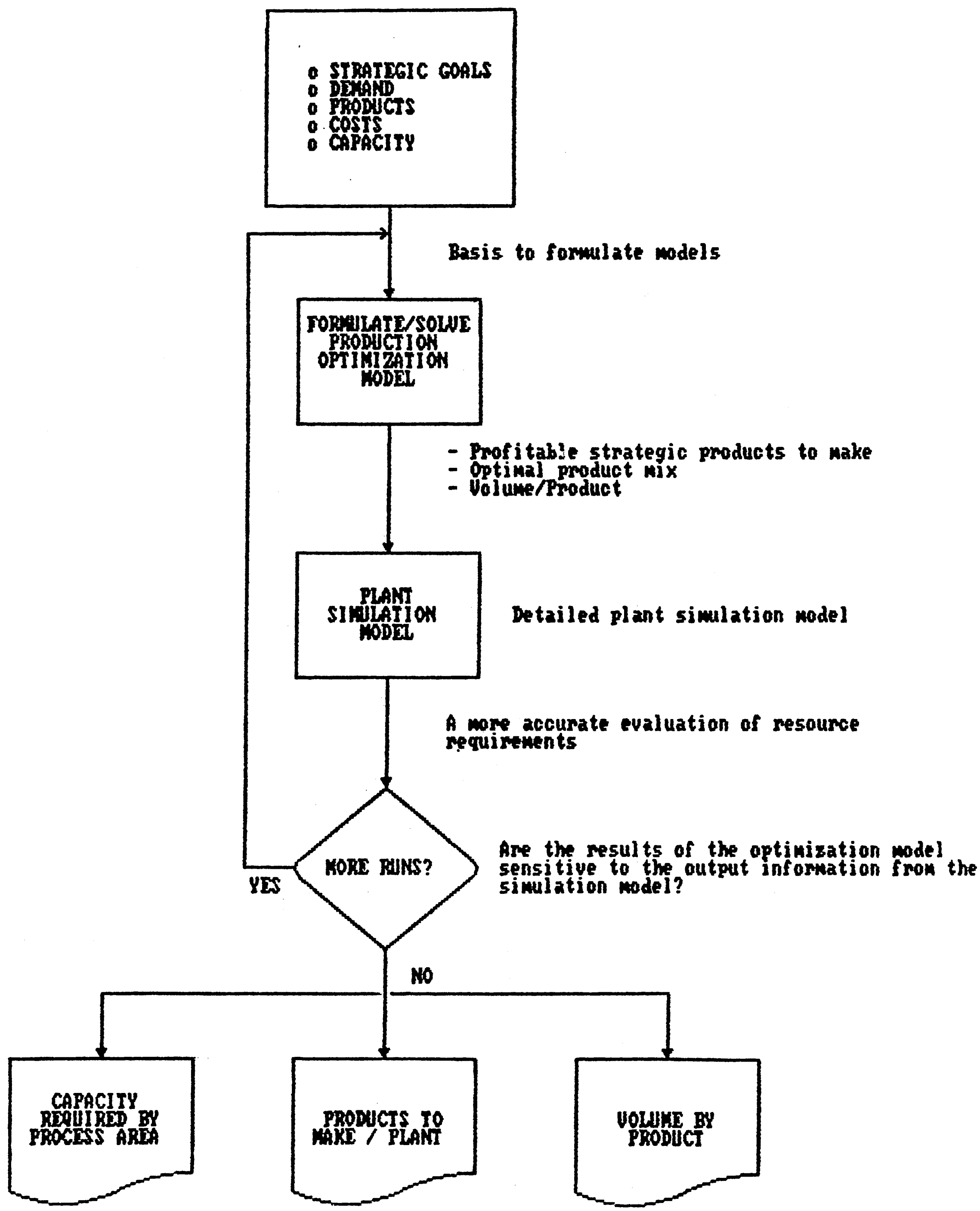


Figure 7.17. Production-Capacity Planning External Models (Finite Loading Assumption)

subject to internal (technological parameters and resource availability) and external (demand, market conditions, government regulations, etc.) constraints as perceived by its management.

The results of the analysis developed with the external modeling aids, basically capacity, product mix/quantities (Figure 7.17) are the input of important relations (Section 7.3.7). This information is presented to the user as well as the information of current and expected production quantities usually determined by management "quotas", to alert the decision maker of the optimization results. The operation under this assumption is depicted in Figure 7.18. The functions corresponding to this module appear in Appendix F, Section 1.1.5.

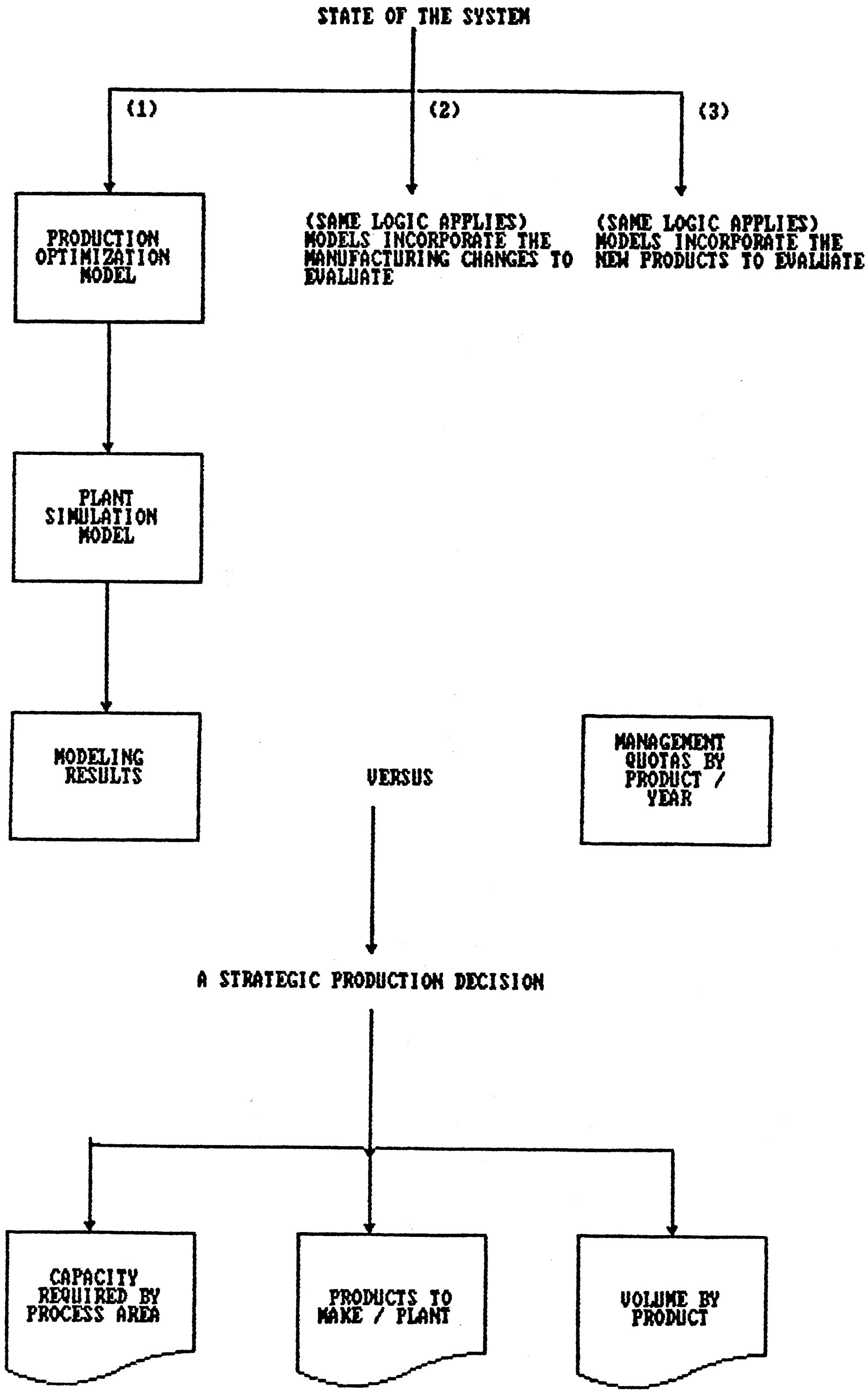


Figure 7.18. Demand/Supply-Capacity Evaluation (Finite Loading Assumption)

7.4.1.6 Product Market Evaluation. Given the diversity of consumer tastes, a successful marketing strategy has required the identification of the segments of consumer demand within which tastes and purchasing power were relatively uniform and offering those segments the products that closely match each segment's consumer expectations.

The input relations (Section 7.3.8) contain the information utilized in this module, having separate relations for the different states of the system for each firm. The product and logistic's characteristics explained in section 7.3.5 basically indicate customer requirements, which are then compared to actual or expected performance of the same characteristics. This is performed through Monte Carlo simulation, to obtain the average and standard deviation of the percentage of time a specific characteristic meets customer expectations. The SMP-DSS considers, for the purpose of this research, generation of normal random numbers. The results of the simulation model are used in master relations, due to the criticial importance of the measure of performance derived from this module.

The same analysis is applied to the firm and the three major competitors. These results form the basis to determine the relative position of the firm in the industry based on the customer's viewpoint of the critical physical and logistic attributes or characteristics. A multicriteria weighting technique was used to accomplish this objective. Figure 7.19 shows a general diagram of the operation of this module.

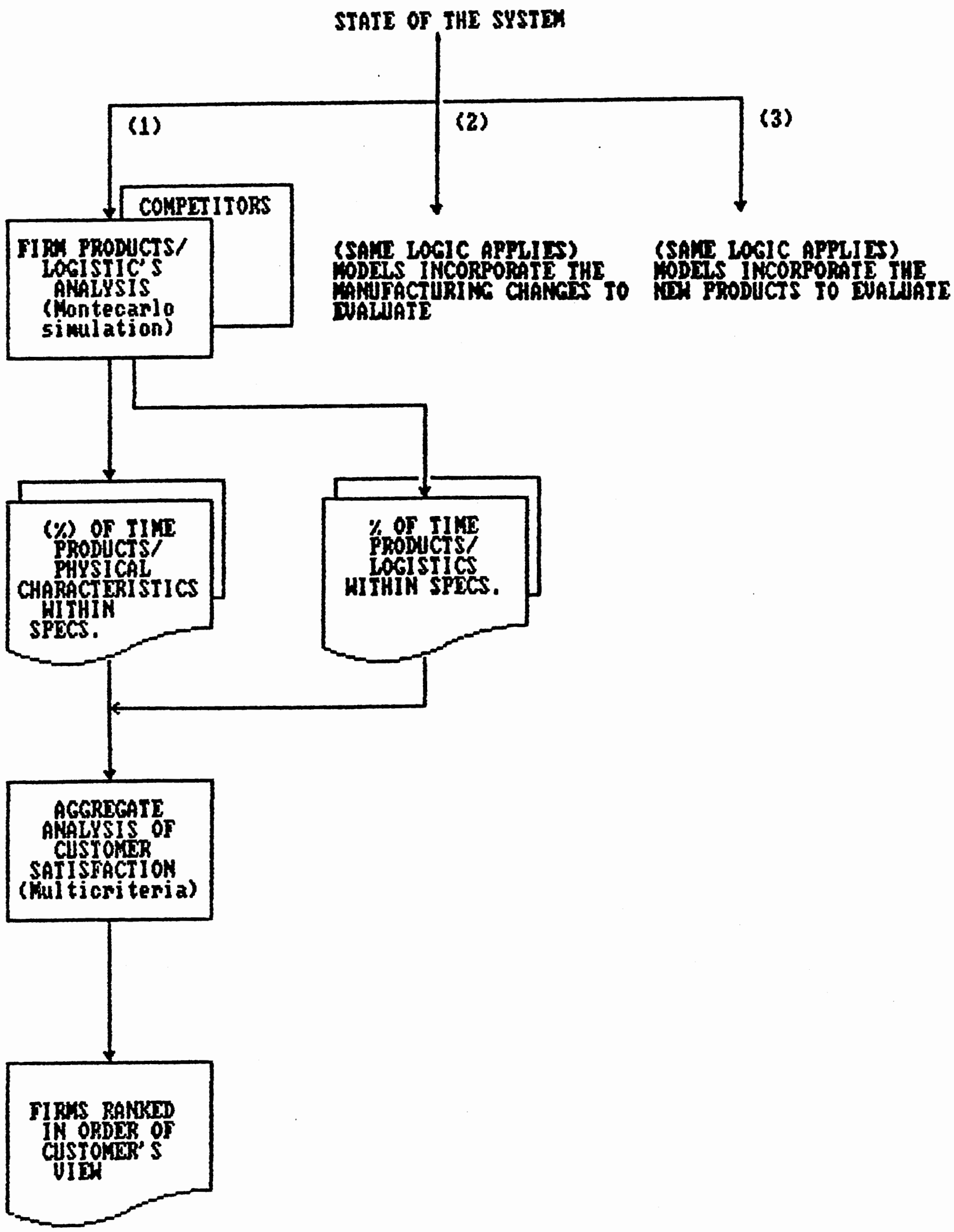


Figure 7.19 Product-Market Evaluation

The adapted multicriteria technique is described next.

$X = \{x^1, x^2, \ldots, x^m\}$ denotes the set of alternatives (firms) and each alternative is characterized by having n critical product p attributes of importance to the customer. For example, the kth alternative can be written as

$$x^k = \{x^k_1, x^k_2, \ldots, x^k_n\} \qquad k=1,\ldots,m$$

Individual x^k_i designate the level of attribute i attained by firm k, where $i=1,\ldots,n$; $k=1,\ldots,m$.

Thus, x^k is simply a vector of n numbers, assigned to each x^k and summarizing the available information about x^k in terms of incommensurable, quantitative and qualitative, attributes and criteria (Zeleny, 1985).

The set X generates m numbers, a vector

$$x_i = (x^1_i, \ldots, x^m_i)$$

representing the currently achievable scores or levels of the ith attribute. Their simplest interpretation occurs when we assume that more is always preferred to less (or vice versa), since

$$\min_k x^k_i = \max_k (-x^k_i) \qquad k=1,2\ldots,m$$

Among all achievable scores for any ith attribute, x_i, there is at least one extreme or ideal value that is preferred to all others.

$$x^*_i = \max_k x^k_i \qquad i=1,2,\ldots,n$$

The x^*_i is called the "ideal alternative" or the "ideal" denoted as

$$x^* = (x^*_1, \ldots, x^*_n)$$

Consider vector x_i of available scores of the ith attribute over m alternatives. The degree of closeness of x^k_i to x^*_i is defined as

$$d(x^k_i, x^*_i) = d^k_i$$

where $d^k_i = 1$ if $x^k_i = x^*_i$ and otherwise $0 < d^k_i < 1$. Essentially the ith attribute's scores are now viewed as a fuzzy set, defined as the following set of pairs:

$$\{x^k_i,\ d^k_i\} \quad i = 1, \ldots, n \ ; \ k = 1, \ldots, m$$

Where d^k_i is a membership function mapping the scores of the ith attribute into the interval [0,1]. For example, the scores generated by available alternatives might be labeled with respect to the ideal as "close," "not close," "very close," "not very close," "distant," "not distant," "not very distant," "not close and not distant," etc.

If x^*_i is a maximum, then

$$d^k_i = \frac{x^k_i}{x^*_i}$$

(Definition used in the SMP-DSS functions; the higher the percentage of time customer requirements are met, the higher the ranking of the firm from the customer's viewpoint).

If x^*_i is a minimum, then

$$d^k_i = \frac{x^*_i}{x^k_i}$$

The above functions d^k_i indicate that x^j is preferred to x^k when $d^k_i < d^j_i$. The major purpose of using membership functions is to have the critical physical characteristic measures and the logistics measure of performance (cost, quality, responsiveness, etc.) on the same scale (0,1), which allows the user to see the effect of changes of different and conflicting parameters on a uniform single measure. This is accomplished by using a composite membership function which is explained next.

Let d^k_i represent the degrees of closeness of x^k_i to x^*_i. The set of firms X has been mapped through d^k_i's into a "distance" space. The space of all d^k_i's generated by X is D.

The ideal alternative is now translated into a unitary vector, $d^* = (d^*_1, \ldots, d^*_n) = (1, \ldots, 1)$, because if

$$x^k_i = x^*_i \quad \text{then} \quad d^k_i = d^*_i = 1$$

To determine the degree of closeness of any x^k to x^* in terms of d^k and d^*, an appropriate family of distance membership functions can be defined as follows:

$$L_p(\beta,k) = \left[\sum_{i=1}^{n} \beta^p_i \, (1-d^k_i)^p \right]^{1/p}$$

where $\beta = (\beta_1, \ldots, \beta_n)$ is a vector of attribute importance levels β_i, and the power p represents the distance parameter, $1 \le p \le \infty$. Thus, $L_p(\beta,k)$ evaluates the distance between the ideal alternative d^* and the actual vector of degrees of closeness induced by an alternative d^k.

Observe that for p = 1, and assuming $\Sigma \beta_i = 1$, we can write $L_p(\beta,k)$ as

$$L_1(\beta,k) = 1 - \sum_{i=1}^{n} \beta_i d^k_i$$

Similarly for p = 2, we obtain

$$L_2(\beta,k) = \left[\sum_{i=1}^{n} \beta^2_i \ (1-d^k_i)^2\right]^{1/2}$$

and for $p = \infty$:

$$L_\infty(\beta^k) = \max_i \ \{\beta_i(1-d^k_i)\}$$

The APL functions that perform the evaluations of this module are found in Appendix F, Section 1.1.6.

7.4.2 Environmental Scanning

The environmental scanning module of the SMP-DSS provides vital information to a strategic planning committee in order to define or modify the generic strategy of the firm. This module calculates annual changes (in percentage) from a past base year of selected economic, market and suppliers indicators (Appendix C, sections 1.2.1, 1.2.3 and 1.2.4 contains the APL functions). It also performs similar evaluations for competitors as the ones described for the firm, for the following factors:

a) Competitive advantage analysis (Section 7.4.1.2)

b) Financial evaluation (Section 7.4.1.3)

c) Flexibility evaluation (Section 7.4.1.4)

d) Aggregate demand/supply capacity evaluation (Section 7.4.1.5)

e) Product-market evaluation (Section 7.4.1.6)

These functions appear in Appendix F, Section 1.2.2.
The output module is presented in combination with a real example used for the verification and validation of the SMP-DSS.

7.5 SMP-DSS Structure Modules

The creation of the data base and the structure of the hierarchical system are defined in this module.

1. The data base generation function is interactive, and basically defines the dimensions of the relations to be used by the system. The matrices are initialized to zero.

The input required refers to:

- Number of strategy options
- Number of product / process matching options
- Number of life cycle stages
- Number of MOP to consider by master relation defined
- Number of economic factors to consider
- Number of supplier factors to consider
- Number of income statement concepts
- Number of balance statement concepts
- Number of product lines
- Number of critical physical characteristics
- Number of logistic characteristics
- Number of new product lines
- Number of critical physical characteristics (new products)
- Number of logistics characteristics (new products)
- Number of history years to consider
- Number of future years to consider
- Number of critical manufacturing technologies
- Number of new critical manufacturing technologies
- Number of process areas
- Number of processing time concepts
- Number of yield concepts
- Number of utilization factors
- Number of financial ratios

Appendix B has all of the input relations which reflect the dimensions entered in this module. The data base generation function is listed in Appendix H.

2. The generation of the hierarchical system structure follows the general guidelines described in Chapter 6 to implement an application using GEESSI. The SMP-DSS allows

this to be done interactively. The operating tables that have to be defined are:

1. The relation names (MRL)
2. The concept names (MCN)
3. The row concepts / relation (MRC)
4. The column concepts / relation (NC)
5. The evaluation matrix (MDC)
6. The relations / evaluation (RCA)
7. The number of column concepts / relation (VRF, VFC)
8. The number of row concepts / relation (VNC)

1. MRL is a character matrix (n, 72), where n is the number of relations defined.

2. MCN is a character matrix (m, 72), where m represents the number of concepts used by the system.

3. MRC is a numeric matrix (n, 32). It contains the row concept numbers used by a relation. The numbers represent the MCN rows that form the relation.

4. NC is a numeric matrix (n, 12). It has the column concept numbers used by a relation. The numbers represent the MCN columns that form the relation.

5. The evaluation matrix (β, 5) tells the system the function used and the level of execution for each relation, where β is the number of relations that are calculated. The columns on MDC indicate:

1) Relation Number
2) Not used for this application (0)
3) Index (serialization parameter, if relation uses more than one function)

4) Function number

5) Calculation level

Ex:	551	0	1	59	8	(Row 93)
	551	0	2	61	9	(Row 101)

Relation 551 is calculated by function 59, after all lower level relations (1-7) have been calculated. Then function 61 calculates relation 551 with the information it had before and the relations specified in RCA.

6. RCA (β, 10) specifies the relations used in the calculation of each evaluation matrix. It is a one-to-one row correspondence to MDC. As an example for relation 551, the corresponding row in RCA is:

551	552	0	0	0	0	0	0	0	0	(Row 93)

meaning that relation 551 in MDC uses relation 551 and 552 for its evaluation. The system brings such relations and executes the corresponding function. GEESSI provides such operation automatically. It also offers direct access to relations from the function itself.

7. The number of column concepts per relation is recorded in vector VRF of dimension (n), indexing to VFC (f) which contains the formats defined (f).

8. The number of row concepts / relation is defined in vector VNC of dimension n.

The operating tables of the case example are presented in Appendix I. The logic of the functions that generate the output relations is explained in section 7.4 of this chapter.

7.5.1 Remarks

The structure of the SMP-DSS is easily changed through the use of this module. Any relation or order of execution can be modified. The major job resides in the function development if different logic to evaluate a relation is desired. However, the user does not have to establish the links between the relations and functions, since the system takes care of such tasks by the use of GEESSI.

CHAPTER VIII

RESULTS AND VALIDATION OF THE SMP-DSS

8.1 Introduction

As a way to verify and validate the different modules' results and their integration as a strategic manufacturing planning decision support system (SMP-DSS), a real example is presented in this chapter. The steel firm, HYLSA, located in Puebla, Mexico, was selected as an example because of several advantages. It is a worldwide competitive company. Basically, it is a continuous flow type of manufacturing firm, with minimal production interruptions. Information availability and top level management involvement were key factors in the decision to use this firm. Personal modeling development and consulting with them for the last eight years (five years full time and three years part time) were also important factors.

HYLSA is an integrated steel firm, that is, their production processes start from iron ore treatment, continuing with the furnace shop and finishing with the rolling mill processing area (Figure 7.12). The firm has three end product lines, but the intermediate billet products are also sold, depending on the profitability of the end-products (this situation is handled by an optimization model). Therefore, six different product types (around 30 products) are considered for this example, since they have different market requirements.

There are three major integrated competitors in Mexico with the same product lines. They are considered in the example to verify the functions and relations corresponding to each competitor and the functions requiring information from all the major competitors (e.g., functions on competitive advantage analysis and firm ranking by customer satisfaction).

The high inflationary environment prevailing in the firm's country requires careful consideration of economic indicators as well as the financial position of the firm.

Part of the information of the firm was provided by the Engineering Planning Corporate Director. For the rest of the relations, reasonable estimates and adjustments to parameters had to be performed through system calibration (experimentation), to match some critical current factors known in advance. The same was done in generating information regarding the three competitors.

The input relations and all of the evaluations that the SMP-DSS considers are explained in detail in Chapter 7. As mentioned before, the input relations for this example are found in Appendix B, and the evaluation functions are in Appendix F.

This chapter presents the current assessment of the firm, and as a result of this, the evaluation of a set of proposed changes to manufacturing operations, and the evaluation of the firm's performance with the proposed introduction of three new products. The SMP-DSS output modules contain the results of the evaluation modules, expressed also as relations. Refer to Appendix C for output relations not presented or discussed in this chapter. Since this is a modular system, it was feasible to verify the correct operation of each module and the integration of all the elements of the system.

8.2 Results of the Current Assessment of the Firm Using the SMP-DSS

As was mentioned in Chapter 5, a current assessment analysis is an important step in the strategic planning process. The results from this state of the system in the SMP-DSS are always available for comparison with the results from changes to any input relation.

For this case, the year of analysis is 1987, and the projections are based on the assumptions that the current manufacturing operations and product lines follow their current life cycles. That is, no major changes in manufacturing and product lines are in effect. The evaluation of the changes to operations is examined later.

The results presented in this chapter emphasize the need for repositioning the firm's strategy, which causes one to think about alternative manufacturing changes; this option is discussed in the next section of the chapter. These results will be shown to validate the system, since they reflect the actual 1987 position and direction of the firm.

The following output modules' results are discussed:

1) Business strategy and manufacturing strategy consistency evaluation results

2) Competitive advantage analysis results

3) Financial evaluation results

4) Product / Process matching evaluation results

5) Aggregate capacity evaluation results

6) Product market evaluation results

1. The relations calculated in this module form the highest level of the hierarchy of the SMP-DSS requiring information from different modules, which form one or more levels of relations.

The firm positions itself in the overall cost, generic strategy category, basically from the selection of billet-N/rods in the past, as its major product line. Its high demand and production volume and emphasis on cost (see input master relations in Appendix B), created economies of scale that reinforced such a strategy. The market requirements for the other product lines (Appendix B, Section 5) were very different, so the firm was trying to establish a feasible differentiation strategy for billet-B/wire L.C. and billet-A/cables. There were many conflicts across functional areas and management levels because of the need to compromise decisions in situations where a common factor affected all product lines.

Figure 8.1 shows the target generic and by product business strategies in the left column and the SMP-DSS results on the right, reflecting the mapping of manufacturing, market financial and economic actual MOP into the strategy that better match such actual measures of performance.

HYLSA PUEBLA 20/ABR/88 22:17 HRS

MANUFACTURING STRATEGY CONSISTENCY ANALYSIS (current)

	GENERIC BUSINESS STRATEGY	FROM ANALYSIS
GENERIC	OVERALL COST_MEDIUM	OVERALL COST_MEDIUM
BY PRODUCT BILLET_N	OVERALL COST_MEDIUM	OVERALL COST_MEDIUM
BILLET_B	DIFFERENTIATION_HIGH	DIFFERENTIATION_HIGH
BILLET_A	DIFFERENTIATION_MEDIUM	DIFFERENTIATION_MEDIUM
RODS	OVERALL COST_MEDIUM	OVERALL COST_MEDIUM
WIRE L.C	DIFFERENTIATION_MEDIUM	DIFFERENTIATION_MEDIUM
CABLES	DIFFERENTIATION_MEDIUM	DIFFERENTIATION_HIGH

Figure 8.1. Consistency Strategy Evaluation Results

The weighted percentage of measures of performance accomplished is given in Table 8.1 (generic, and by product). Recall that each MOP has a different weight. For example, on the aggregate (generic), the sum of weights of the MOP that fall within the overall cost-medium strategy is 61% (level of consistency). Appendix C, Section 1.1.1, includes all the output supporting relations, showing the MOP that the generic and by product master relations consider for this example. Each of them is explained in the evaluation module section in Chapter 7.

TABLE 8.1

CONSISTENCY STRATEGY EVALUATION RESULTS
YEAR OF ANALYSIS: 1987

	BILLET-N	BILLET-B	BILLET-A
Weighted % of key product MOP accomplished	93.0	61.0	53.0
Generic strategy (code)	2.0	4.0	5.0
	RODS	WIRES LC	CABLES
Weighted % of key product MOP accomplished	70.0	59.0	57.0
Generic strategy (code)	2.0	5.0	4.0
			VALUE
Weighted % of key generic MOP accomplished			61.0
Generic strategy (code)			2.0

The results in Table 8.1 indicate, in relative terms, that the firm is accomplishing the billet-N/rods intended strategy with 93 and 70% effectiveness, respectively. The results for the other products are within the target strategy, except for cables; however, all of these strategies are only being partially accomplished. In general, the results indicate prompt strategic action. Other output modules complement this evaluation.

2. The results in this section are a sample of what can be done with this module. The relative contribution of the firm's strategy to the achievement of the firm's competitive advantage is analyzed by selecting one MOP per category (refer to Section 7.1.2):

- Return on assets (ROA) (%)
- Weighted manufacturing value added per ton/m^2 (WCOST/m^2) \$/m^2
- Yield of billet-N (TAL/TCM) (%)

The first two MOP are aggregate measures, while the last one is a product measure. The independent results for each MOP are shown in Tables 8.2 and 8.3 (the simulation generates 50 observations and the statistical tests are performed with $\alpha = .05$)

TABLE 8.2

AVERAGE MOP VALUES BY FIRM

		FIRMS			
MOP		1(HYLSA)	2	3	4
1.	ROA	6.00	6.12	6.00	6.05
2.	WCOST/m^2	21.00	23.00	26.00	21.10
3.	TAL/TCM	93.20	88.50	83.90	93.20

The firm is achieving an acceptable return on assets. Its expected trend after introducing the manufacturing changes and new products is significantly different from that of competitors (Section 8.4). There is a significant advantage with respect to competitor 3 in total costs by ton/m^2; and also in the critical aspect of yield of billet-N. These factors are currently not impacting return on assets as much as they are on the product-market analysis, presented later, which facilitates the introduction of new products.

3. The 1987 financial ratios of the firm and competitors are presented in Table 8.4.

TABLE 8.3

RELATIVE COMPETITIVE ADVANTAGE
ANALYSIS RESULTS

1. ROA

o There is not a significant difference between firms, on the average, for the MOP selected.

2. WCOST/m² (* = significant difference)

	1(HYLSA)	2	3	4
1(HYLSA)			*	
2			*	
3	*	*		*
4			*	

o There is a significant difference between firms, on the average, for the MOP selected.
o There is a significant difference between firms 3 and 1, on the average, for the MOP selected.
o There is not a significant difference between firms 4 and 1, on the average, for the MOP selected.
o There is not a significant difference between firms 2 and 1, on the average, for the MOP selected.

3. TAL/TCM (* = significant difference)

	1(HYLSA)	2	3	4
1(HYLSA)			*	
2				
3	*			*
4			*	

o There is a significant difference between firms, on the average, for the MOP selected.
o There is a significant difference between firms 1 and 3, on the average, for the MOP selected.
o There is not a significant difference between firms 1 and 2, on the average, for the MOP selected.
o There is not a significant different between firms 1 and 4, on the average, for the MOP selected.

TABLE 8.4

FINANCIAL RATIOS BY FIRM

FINANCIAL RATIOS	1(HYLSA)	2	3	4
1. Current Assets/ Liabilities (times)	2.3	2.3	2.3	2.3
2. ACID (times)	1.3	1.3	1.3	1.3
3. Debt to Total Assets (%)	50.0	50.0	50.0	50.0
4. Inventory Turns (times)	10.0	10.2	10.0	10.1
5. Fixed Assets Turns (times)	2.3	2.4	2.3	2.3
6. Total Assets Turns (times)	1.5	1.5	1.5	1.5
7. Margins on Sales (%)	4.0	4.0	4.0	4.0
8. Return on Assets (%)	6.0	6.1	6.0	6.1
9. Return on Net Worth (%)	12.0	12.3	12.0	12.1

The 1987 information for each competitor in the system is different, but it was kept proportional to HYLSA's information on purpose to verify the different functions by firm. That is why the current financial ratios across firms are similar. The master relations of the firm includes some of these MOP (return on assets, debt to total assets and inventory turns) that are considered to have different degrees of accomplishment or application under each generic strategy for the firm and industry in question.

Appendix C, Section 1.1.3, contains the output relations that are available for this module. The relations show the past, current and projected absolute financial ratios and trends calculated by each firm. The projections reflect the changes to manufacturing operations explained in Section 8.3.

4. The current assessment of the position of the firm's product(s)/process(es) matching level is shown in Figure 8.2 (refer to Section 7.1.4 for an explanation of the levels considered in the product/process matrix).

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PRODUCT / PROCESS MATCHING ANALYSIS (current)

	MATCHING LEVEL EXPECTED NOW	FROM ANALYSIS
GENERIC	2. DESIRABLE	2. DESIRABLE
BY PRODUCT BILLET_N	2. DESIRABLE	2. DESIRABLE
BILLET_B	3. TRANSITION	3. TRANSITION
BILLET_A	3. TRANSITION	3. TRANSITION
RODS	2. DESIRABLE	1. MOST DESIRABLE
WIRE L.C	3. TRANSITION	3. TRANSITION
CABLES	3. TRANSITION	3. TRANSITION

Figure 8.2. Product/Process Matching Performance

The generic category of matching expected in 1987 is the same as the resulting one from the analysis (desirable), but fulfilling 92% of the weighted measures of performance considered on the generic product/process master relation. Table 8.5 shows that 13% of the total corresponds to the "most desirable" category. From Figure 8.2 and Table 8.6 the by product/process performance indicates that the major product line billet-N is at a "desirable" level, as expected, but at 85% of full target accomplishment. Partial fulfillment is accomplished at the "most desirable" level at 32%.

The declining maturity stage on the life cycle of the electric furnaces and the continuous casting machines, which causes quality problems, is the main factor affecting the attainment of better results for the product (Appendix C, Section 1.1.7 presents all the supporting output relations).

The other product lines are at a "transition" level (for billet-A/cables : 69% and 65% correspond to higher levels of performance respectively, see Table 8.6, and for billet-B/wires the level of matching is very similar). The transition stage for these two product lines with respect to the manufacturing processes is explained basically because of the lack of processing capabilities to satisfy the manufacturing velocity and quality requirements needed to compete on these markets (Appendix C, Section 1.1.4).

The dilemma of whether to remain an overall cost leader, high volume firm confronting the increasing concentration of rods-milling firms, or to switch to a clear differentiated specialized firm, was a major concern of the top management.

The flexibility model results are used as a MOP in the master relations, since the degree of flexibility varies with the strategy in action. They are also valuable as independent information as many other output relations of the

SMP-DSS (Appendix C). The flexibility results that indicate the relative contribution of critical characteristics to the achievement of new products are shown in Table 8.7. Section 8.4 describes the effect of the three new products' introduction on the performance of the system.

TABLE 8.5

GENERIC PRODUCT/PROCESS MATCHING RESULTS
YEAR OF ANALYSIS: 1987

	VALUE
Weighted % of key generic MOP accomplished	92.0
Level of matching (1 = most desirable . . .)	2.0

	WEIGHTS
Most Desired	13.0
Desirable	79.0
Transition	8.0
Rare Match	0.0
No Match	0.0
None	0.0

The interpretation of the relative values, indicate that the knowledge gained in achieving "surface quality" is valuable to the firm in achieving the three new products (for this case the feasible index ranges from 1 to 10). However, for the other characteristics also required for the new products (with values around 6), it is necessary to have processing improvements or changes to operations, to manufacture the new products that meet market requirements. The effect of the proposed changes, explained later, on the flexibility matrix is shown in Section 8.3.

TABLE 8.6

BY PRODUCT/PROCESS MATCHING RESULTS
YEAR OF ANALYSIS: 1987

	BILLET-N	BILLET-B	BILLET-A
Weighted % of key product MOP accomplished	85.0	85.0	69.0
Level of matching (1 = most desirable . . .)	2.0	3.0	3.0

	RODS	WIRES LC	CABLES
Weighted % of key product MOP accomplished	37.0	67.0	65.0
Level of matching (1 = most desirable . . .)	1.0	3.0	3.0

	BILLET-N	BILLET-B	BILLET-A
Most Desired	32.0	0.0	16.0
Desirable	53.0	40.0	10.0
Transition	0.0	45.0	43.0
Rare Match	0.0	0.0	16.0
No Match	0.0	0.0	0.0
None	0.0	0.0	0.0

	RODS	WIRES LC	CABLES
Most Desired	37.0	9.0	17.0
Desirable	32.0	26.0	10.0
Transition	4.0	32.0	38.0
Rare Match	0.0	6.0	8.0
No Match	0.0	0.0	0.0
None	0.0	0.0	0.0

Table 8.8 presents the relative value of the current product lines to the achievement of new products. As expected, product line 5 (Wires L.C.) is the most valuable to the company in that respect. However, there is not a clear distinction, since the actual processing capabilities do not allow the attainment of better results for Wires L.C. and Cables. The end product lines are all more valuable than the

intermediate (billet) products, by 36%, 50%, and 48%, since the new products to be introduced utilize the end manufacturing processes of the current product lines. The product code with the highest index in the flexibility matrix is the value used to compare with the value entered on the flexibility concept on the master relation.

TABLE 8.7

FLEXIBILITY RESULTS BASED ON
PHYSICAL CHARACTERISTICS
YEAR OF ANALYSIS: 1987

	INDEX
Tensile Strength	6.9
Rolling Strength	6.3
Carbon	6.4
Manganese	6.4
Length	4.3
Surface Quality	7.5

TABLE 8.8

FLEXIBILITY RESULTS BASED ON
CURRENT PRODUCT LINES
YEAR OF ANALYSIS : 1987

	INDEX
Billet-N	5.8
Billet-B	5.4
Billet-A	5.2
Rods	7.9
Wires LC	8.1
Cables	7.7

The same calculations on flexibility are performed for competitors (Appendix C, Section 1.1.4, presents the results), which are a valuable source for strategic decisions.

5. The current aggregate firm demand/supply analysis results are shown in Table 8.9. There is a potential total marginal billet demand of 180 tons by 1993, and 162 tons of end product.

TABLE 8.9

AGGREGATE FIRM DEMAND/SUPPLY DIFFERENCE
YEAR OF ANALYSIS: 1987

	BILLET-N	BILLET-B	BILLET-A
1984	-18.0	-4.0	-2.0
1985	-19.0	-5.0	-3.0
1986	-20.0	-6.0	-3.0
1987	-20.0	-7.0	-6.0
1988	-36.0	-6.8	-21.5
1989	-36.3	-16.8	-21.8
1990	-60.5	-21.8	-32.5
1991	-76.3	-32.3	-43.0
1992	-65.8	-48.0	-53.5
1993	-78.4	-48.0	-53.5
	RODS	WIRES LC	CABLES
1984	-16.7	-4.0	-2.0
1985	-16.7	-4.6	-2.6
1986	-18.2	-5.1	-2.5
1987	-18.5	-7.0	-6.0
1988	-32.4	-6.1	-19.4
1989	-32.6	-15.1	-19.6
1990	-54.4	-19.6	-29.3
1991	-68.6	-29.0	-38.7
1992	-59.2	-43.2	-48.2
1993	-70.5	-43.2	-48.2

The results of the required capacity for the firm (tons) by process area are given in Table 8.10 and Table 8.11. They are obtained by the models explained in the evaluation module, which use the results in Table 8.9 (Section 7.4.1.5). Lower level relations for the firm and the same type of results generated for each competitor are all included in Appendix C, Section 1.15. Table 8.10 refers to the infinite capacity assumption, and Table 8.11 to the evaluation assuming capacity restrictions (Reference Section 7.1.5).

TABLE 8.10

MARGINAL REQUIREMENT BY PROCESS AREA (TONS)
YEAR OF ANALYSIS : 1987
INFINITE LOADING CAPACITY
(SURPLUS OR -SHORTAGE OF PRODUCTION)

	1988	1989	1990
Iron Ore	-134.9	-156.9	-240.8
Reduction Process	-101.2	-127.7	-180.6
Electric Furnaces	-134.2	-156.1	-239.6
Continuous Casting Machines	-127.8	-148.6	-228.2
Rolling Mill	- 57.8	- 67.3	-103.3
	1991	**1992**	**1993**
Iron Ore	-318.0	-351.6	-377.8
Reduction Process	-238.5	-263.7	-283.3
Electric Furnaces	-316.4	-349.5	-375.7
Continuous Casting Machines	-301.3	-332.6	-357.6
Rolling Mill	-136.4	-150.5	-161.9

TABLE 8.11

PRODUCTION BY PROCESS AREA (TONS)
YEAR OF ANALYSIS: 1987
FINITE LOADING CAPACITY

	BILLET-N	BILLET-B	BILLET-A
1988	437.5	115.0	104.5
1989	432.3	118.8	107.4
1990	434.5	114.0	109.3
1991	434.2	118.8	111.2
1992	427.5	119.7	114.0
1993	432.3	118.8	114.0

	RODS	WIRES LC	CABLES
1988	393.8	103.5	94.1
1989	389.1	106.9	96.6
1990	391.1	102.6	98.4
1991	390.7	106.9	100.0
1992	384.8	107.7	102.6
1993	389.0	106.9	102.6

	TMIN	TFE	TAL	TBB	TPT
1988	683.5	512.6	681.2	649.4	591.4
1989	684.9	513.7	682.5	650.7	592.6
1990	684.3	513.33	681.9	650.1	592.0
1991	690.9	518.2	688.4	656.3	597.6
1992	688.0	516.0	685.5	653.3	595.1
1993	691.9	519.0	689.5	657.2	598.5

The tables show the capacity required to meet 100% of the demand and the production assigned under capacity restrictions. The emphasis was indeed on billet-N/rods in 1987, but the marginal contribution with respect to other products was decreasing and the level of concentration and competition was increasing at such a level, that the firm decided to redefine its mission. The personal knowledge of the current situation of the firm is very useful for the interpretation of the results of the SMP-DSS.

6. The product market evaluation results (Table 8.12), indicate that the firm meets market requirements "better" than the competition for most of the product lines with respect to the product characteristics and the logistics MOP selected. However, the performance of all the firms are far from customer's desires (Appendix C, Section 1.1.6), since imports were not allowed. With the opening of Mexico in 1988 to the General Agreement of Tariffs and Trades (GATT), the position of the firm had to change to remain competitive.

The output relations from the simulation of the average percentage and standard deviation of time conforming to specifications are presented in Appendix C, Section 1.1.6. These results are then used in the weighting ranking model, from which Table 8.12 results (reference Chapter 7).

TABLE 8.12

FIRM'S RANKING BASED ON CUSTOMER SATISFACTION (*)

FIRM'S RANK	BILLET-N	BILLET-B	BILLET-A
1	HYLSA (0)	HYLSA (0)	HYLSA (0)
2	COMP1 (3.7)	COMP1 (2.1)	COMP3 (0.1)
3	COMP3 (6.6)	COMP3 (5.8)	COMP1 (1.6)
4	COMP2 (27.5)	COMP2 (13.6)	COMP2 (6.2)

FIRM'S RANK	RODS	WIRE LC	CABLES
1	HYLSA (0)	HYLSA (0)	HYLSA (0)
2	COMP1 (.7)	COMP1 (.2)	COMP3 (3.4)
3	COMP3 (2.3)	COMP3 (4.8)	COMP1 (4.1)
4	COMP2 (11.8)	COMP2 (12.1)	COMP2 (15.4)

* Based on a L2 Distance Measure (Compromise minimization distance from ideal)

The relative distance measures, in parenthesis in Table 8.12, indicate, as explained in chapter 7, an overall relative measure of the distance of the firm product's characteristics and logistic's performance from the "best" in the set for that product. The measure ranges from 0 to 100. Note the closeness of HYLSA and competitor 1 in general. The frequent use of the (0,1) scale facilitates its interpretation.

8.2.1 Proposed Changes to Manufacturing Operations and New Products Introduction

The 1987 assessment analysis of the firm by the SMP-DSS is considered to be a valid approximation of the real situation. The most important aggregate results and conceptual basis of the SMP-DSS were presented to the Engineering Planning Corporate Director of HYLSA, to validate some of the most important relations for the company.

As was stated before, the results presented reflect the need for repositioning the firm's strategy. It was proposed then, to simulate several changes to the manufacturing operations of the firm. A group of 21 different alternatives resulted from the combination of key strategic technological changes to the furnace processing area. This extensive simulation study was carried out personally during 1987, by using a large scale simulation model. The results were presented and meticulously verified and validated by the Engineering Planning Corporate Director and his staff. The alternative they decided to implement is the one evaluated by the SMP-DSS and presented in the next section.

8.3 Results of the Changes to Manufacturing Operations

The major changes to the manufacturing operations of the firm are located at the furnace shop area. The changes involve basically:

1) The introduction of two IHI-EBT (Ishikawa, excentric) furnaces

2) The introduction of a high quality pot-furnace (H.O.), and

3) A capacity increase of 80 tons in the rolling mill processing area

These changes will be implemented in three stages that will allow more specialized, differentiated product lines, reflecting a mission redefinition of the firm and, therefore, a shift on strategic choice.

The results of the effect of these changes is presented in two steps:

1) Evaluating the effect of the manufacturing changes on the performance of the system, assuming that no new products are introduced, and

2) Evaluating the effect of the manufacturing changes and the introduction of three new product lines recommended by the marketing research department (Section 8.4).

The purpose of dividing the presentation is to demonstrate the options of the SMP-DSS. For the first case, it is required to select state two of the system when the state menu option appears in the screen. The information that changes involve:

- Master relations (different targets)
- Financial statements (project[s] cash flows impact)
- Expected product characteristics and logistics performance
- Manufacturing capabilities, yields
- Production
- Capacity
- Value added by process area by product

All the input relations for the firm and competitors used for this Section appear with their title and the comment "(changes)" in Appendix B. Since the same type of output relations is available for each state of the system, only a few are presented in this and the next Section. The rest of the supporting relations are found in Appendix C.

The following output modules evaluated by the end of 1993 are discussed here:

1) Financial evaluation results

2) Consistency evaluation results

3) Product/Process matching evaluation results

4) Product market evaluation results

1. The expected cash flows by year, for 6 years, corresponding to the net effect of the manufacturing changes are required to be input in the cash flow matrix. The system calculates the net discounted cash flows adjusted for inflation as explained in Section 7.1.3. This procedure was applied to this example to generate the pro-forma balance and income statements presented in Appendix C, Section 1.1.3. The financial ratios and trends that result from such statements are also included in the appendix.

2. The firm is implementing a high differentiation strategy as its generic intended competitive choice. Figure 8.3 presents the target generic and by product business strategies and the system results after evaluating the effect of the manufacturing changes. The shift in strategy on the aggregate and for each of the products is clearly recognized by the system, comparing with the results in Figure 8.1.

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MANUFACTURING STRATEGY CONSISTENCY ANALYSIS (changes)

	GENERIC BUSINESS STRATEGY	FROM ANALYSIS
GENERIC	DIFFERENTIATION_HIGH	DIFFERENTIATION_HIGH
BY PRODUCT		
BILLET_N	DIFFERENTIATION_MEDIUM	DIFFERENTIATION_LOW
BILLET_B	FOCUS DIFF._HIGH	FOCUS DIFF_HIGH
BILLET_A	FOCUS DIFF._HIGH	FOCUS DIFF_MEDIUM
RODS	DIFFERENTIATION_MEDIUM	DIFFERENTIATION_LOW
WIRE L.C	FOCUS DIFF._HIGH	FOCUS DIFF_HIGH
CABLES	FOCUS DIFF._HIGH	FOCUS DIFF_HIGH

Figure 8.3. Consistency Strategy Evaluation

The firm is changing its highest weighted goal of being cost leader, to a high quality competitive firm, focusing its products to markets that pay off for such a move. The weighted percentage of expected measures of performance to accomplish as a result of the analysis is given in Table 8.13. The rolling mill processing area requires quality improvements also, if the full effect of the changes in the preceding area are to be realized (Reference Appendix C).

TABLE 8.13

CONSISTENCY STRATEGY EVALUATION RESULTS
YEAR OF ANALYSIS: 1993

	BILLET-N	BILLET-B	BILLET-A
Weighted % of key product MOP accomplished	100.0	83.5	93.0
Generic strategy (code)	6.0	10.0	11.0

	RODS	WIRES LC	CABLES
Weighted % of key product MOP accomplished	93.0	78.0	86.0
Generic strategy (code)	6.0	4.0	4.0

	VALUE
Weighted % of key generic MOP accomplished	72.0
Generic strategy (code)	4.0

Appendix C, Section 1.1.1 shows all of the output relations that complement this evaluation.

3. The performance results that the firm accomplishes implementing the changes with respect to the level of matching between its products and processes are presented in Figure 8.4. The generic category of matching expected in 1993 is the same

as the one resulting from the analysis (desirable), but fulfilling 75% of the weighted measures of performance considered on the generic product/process master relation (Table 8.14). The expected low results are due to the low utilization factors of the new furnaces, and the production mix, which does not include the appropriate exploitation of the furnaces (Appendix C, Section 1.1.4) since the new products have not been introduced yet.

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PRODUCT / PROCESS MATCHING ANALYSIS (changes)

	PRODUCT/PROCESS MATCHING DESIRE	FROM ANALYSIS
GENERIC	2. DESIRABLE	2. DESIRABLE
BY PRODUCT		
BILLET_N	1. MOST DESIRABLE	1. MOST DESIRABLE
BILLET_B	2. DESIRABLE	1. MOST DESIRABLE
BILLET_A	2. DESIRABLE	1. MOST DESIRABLE
RODS	1. MOST DESIRABLE	1. MOST DESIRABLE
WIRE L.C	2. DESIRABLE	1. MOST DESIRABLE
CABLES	2. DESIRABLE	1. MOST DESIRABLE

Figure 8.4. Product/Process Matching Performance (Changes)

Note that the expected by product matching for billet-B/wires L.C. and billet-A/cables is a "desirable" one. The results show the "most desired" level of matching, but at low levels: 39/36% and 50/43%, respectively (Table 8.15). The cumulative results at the "desirable" level are 70/71% and 81/72%, respectively, which better match the expected results. The results for billet-N/rods are now on the "most desired" category at 71/53%, comparing with the previous analysis: "desirable" at 83/69%, since these products are now being produced with better quality at lower costs (Appendix C, Section 1.1.4). The manufacturing changes represent a movement along the flexibility dimension of the product/process matrix mentioned in Chapter 5.

TABLE 8.14

GENERIC PRODUCT/PROCESS MATCHING RESULTS
YEAR OF ANALYSIS: 1993

	VALUE
Weighted % of key generic MOP accomplished	75.0
Level of matching (1 = most desirable . . .)	2.0

	WEIGHTS
Most Desired	19.0
Desirable	56.0
Transition	25.0
Rare Match	0.0
No Match	0.0
None	0.0

TABLE 8.15

BY PRODUCT/PROCESS MATCHING RESULTS
YEAR OF ANALYSIS: 1993

	BILLET-N	BILLET-B	BILLET-A
Weighted % of key product MOP accomplished	71.0	39.0	50.0
Level of matching (1 = most desirable . . .)	1.0	1.0	1.0

	RODS	WIRES LC	CABLES
Weighted % of key product MOP accomplished	53.0	36.0	43.0
Level of matching (1 = most desirable . . .)	1.0	1.0	1.0

	BILLET-N	BILLET-B	BILLET-A
Most Desired	71.0	39.0	50.0
Desirable	18.0	31.0	31.0
Transition	4.0	24.0	13.0
Rare Match	0.0	0.0	0.0
No Match	0.0	0.0	0.0
None	0.0	0.0	0.0

	RODS	WIRES LC	CABLES
Most Desired	53.0	36.0	43.0
Desirable	22.0	35.0	29.0
Transition	9.0	13.0	12.0
Rare Match	0.0	0.0	0.0
No Match	0.0	0.0	0.0
None	0.0	0.0	0.0

The effect of the changes to operations on the flexibility model results is shown in Tables 8.16 and 8.17. The improvement on most characteristics that are needed for new products is clearly detected by comparing with Tables 8.7 and 8.8. Note that the "know-how" on wires L.C. and cables is extremely useful in accomplishing the three new product lines because of the similarity of market and production requirements that are better achieved under the new manufacturing environment.

TABLE 8.16

FLEXIBILITY RESULTS BASED ON
PHYSICAL CHARACTERISTICS
YEAR OF ANALYSIS: 1993

	INDEX
Tensile Strength	8.0
Rolling Strength	6.9
Carbon	7.5
Manganese	7.5
Length	4.8
Surface Quality	8.5

TABLE 8.17

FLEXIBILITY RESULTS BASED ON
CURRENT PRODUCT LINES
YEAR OF ANALYSIS: 1993

	INDEX
Billet-N	6.9
Billet-B	6.9
Billet-A	6.7
Rods	8.9
Wires LC	9.9
Cables	9.8

The manufacturing changes add enormous flexibility to the firm, opening several product options.

4. The aggregate firm demand/supply analysis results are shown in Table 8.18. They show that the modification to the furnace shop area is adding around 140 tons of billet of capacity by the end of 1993, since the sum of the uncovered billet demand is 40 tons, and the previous analysis showed 180 tons of potential demand. Such increase in capacity is

documented in the capacity input relation. The linear programming model mentioned in Chapter 7 is used to support the decisions about product mix and inter-plants shipments.

TABLE 8.18

AGGREGATE FIRM DEMAND/SUPPLY ANALYSIS
YEAR OF ANALYSIS : 1993
INFINITE LOADING CAPACITY
(+SURPLUS OR -SHORTAGE OF PRODUCTION)

	BILLET-N	BILLET-B	BILLET-A
1988	-21.0	-6.8	-6.5
1989	-21.3	-6.8	-6.8
1990	-22.5	-6.8	-7.5
1991	-23.3	-7.3	-8.0
1992	-22.8	-8.0	-8.5
1993	-23.4	-8.0	-8.5

	RODS	WIRES LC	CABLES
1988	-18.9	-6.1	-5.9
1989	-19.1	-6.1	-6.1
1990	-20.3	-6.1	-6.8
1991	-20.9	-6.5	-7.2
1992	-20.5	-7.2	-7.7
1993	-21.0	-7.2	-7.7

The results of the estimated capacity by process area required to meet the demand, according to the model of Section 7.1.5, are shown in Tables 8.19 and 8.20 for each of the capacity assumptions (reference Chapter 7, Section 7.1.5).

TABLE 8.19

MARGINAL REQUIREMENTS BY ROCESS AREA (TONS)
YEAR OF ANALYSIS : 1993
INFINITE LOADING CAPACITY
(+SURPLUS OR -SHORTAGE OF PRODUCTION)

	1988	1989	1990
Iron Ore	- 69.9	- 71.0	- 75.1
Reduction Process	- 52.5	- 53.2	- 56.3
Electric Furnaces	- 69.7	- 70.7	- 74.7
Continuous Casting Machines	- 68.1	- 69.1	- 73.1
Rolling Mill	- 30.8	- 31.3	- 33.1
	1991	**1992**	**1993**
Iron Ore	- 78.6	- 80.2	- 81.4
Reduction Process	- 59.0	- 60.1	- 61.1
Electric Furnaces	- 78.3	- 79.8	- 81.1
Continuous Casting Machines	- 76.6	- 78.0	- 79.2
Rolling Mill	- 34.7	- 35.3	- 35.9

Recall that under the finite capacity assumption, the system provides the choice of using the results of the optimization model or the management production "quotas", since the selection made is used to feed master relations. For this example, the optimization model results are always used.

5. The product-market evaluation results (Table 8.21) reflect a similar ranking among the firms in the set. However, the individual characteristics and logistics performance results are much closer to market requirements (Appendix C, Section 1.1.6).

TABLE 8.20

PRODUCTION BY PROCESS AREA (TONS)
YEAR OF ANALYSIS: 1993
FINITE LOADING CAPACITY
(CHANGES)

	BILLET-N	BILLET-B	BILLET-A
1988	451.0	135.0	125.0
1989	455.0	140.0	130.0
1990	450.0	150.0	145.0
1991	450.0	150.0	155.0
1992	450.0	160.0	165.0
1993	455.0	170.0	170.0

	RODS	WIRES LC	CABLES
1988	405.9	121.5	112.5
1989	409.5	126.0	117.0
1990	405.0	135.0	130.5
1991	405.0	135.0	139.5
1992	405.0	144.0	148.5
1993	409.5	153.0	153.0

	TMIN	TFE	TAL	TBB	TPT
1988	721.3	541.0	718.7	702.7	639.9
1989	735.6	551.7	732.9	716.5	652.5
1990	756.2	567.23	753.2	736.3	670.5
1991	766.5	574.9	763.4	746.2	679.5
1992	787.0	590.3	783.7	766.0	697.5
1993	807.4	605.5	804.0	785.8	715.5

Remember that the SMP-DSS selects the appropriate functions and relations to evaluate the results presented in Appendix C, that is, it has separate evaluation functions and relations for each state of the system.

TABLE 8.21

FIRM'S RANKING BASED ON CUSTOMER SATISFACTION (*)

FIRM'S RANK	BILLET-N	BILLET-B	BILLET-A
1	HYLSA (0)	HYLSA (0)	HYLSA (0)
2	COMP1 (5.4)	COMP1 (0.5)	COMP3 (0.9)
3	COMP3 (11.7)	COMP3 (7.0)	COMP1 (2.4)
4	COMP2 (18.2)	COMP2 (8.2)	COMP2 (10.0)

FIRM'S RANK	RODS	WIRE LC	CABLES
1	HYLSA (0)	HYLSA (0)	HYLSA (0)
2	COMP1 (3.8)	COMP1 (0.1)	COMP3 (1.2)
3	COMP3 (15.3)	COMP3 (6.0)	COMP1 (2.6)
4	COMP2 (20.3)	COMP2 (13.8)	COMP2 (14.5)

*Based on L2 Distance Measures (compromise minimization distance from ideal)

8.3.1 Summary

The alternative selected creates a very promising manufacturing environment. It opens several production alternatives that impose entry barriers to competitors due to the high capital requirements. The expected return on assets trend through 1993 (5.73% net for that year) is considered to be acceptable (high for the type of industry and even more attractive because of the difficult economic environment expected for the next 6 years). The introduction of new products will permit the exploitation of the new manufacturing resources more appropriately.

8.4 Results of the System After Introducing Three New Product Lines

In this section, the effect of the introduction of new products on the performance of the system is analyzed. The new product lines (malla, bars and ac-van) require the new type of furnaces and changes to the furnace shop mentioned before, to meet the demanding requirements of the export markets being served by the company. The production for each product line is still taken from the linear programming model, expanded to include the new products.

The results of the SMP-DSS for this example of state 3 of the system are presented in Appendix C. The input relations used for these evaluations for the firm and competitors appear by category in Appendix B, having the comment "(new products)" appended to the title of the relation. All of the information related to the new products is entered, as well as the information involving compromises among products (e.g., product mix, production cycle, . . .) and in general, the relations that are affected by the influence of the presence of the new products (e.g., old products' demand expectations, product performance, logistics). They involve:

- Master relations (new product targets)
- Financial statements (expected cash flows)
- Expected new products characteristics and logistics performance
- Manufacturing capabilities, yields
- Production
- Capacity
- Value added by process area by product

The following output modules evaluated by the end of 1993 are summarized in this section (Appendix C contains all the results of this module):

1) Financial evaluation results

2) Consistency evaluation results

3) Aggregate capacity evaluation results

1. The expected cash flows for the next six years, including the effect of the introduction of the new processes and products, were entered in the cash flow matrix, that was used to create the pro-forma balance and income statements shown in Appendix C, Section 7.1.3. The financial ratios and trends that result from such statements are also presented in the appendix.

The competitive advantage analysis based on these financial figures shows a significant difference of the firm with respect to competitors (Appendix C).

2. The expected generic and by new product strategies are shown in Figure 8.5.

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MANUFACTURING STRATEGY CONSISTENCY ANALYSIS (new products)

	GENERIC BUSINESS STRATEGY	FROM ANALYSIS
GENERIC	DIFFERENTIATION_HIGH	DIFFERENTIATION_MEDIUM
BY PRODUCT MALLA	FOCUS DIFF._HIGH	FOCUS DIFF_HIGH
BARRA	DIFFERENTIATION_HIGH	DIFFERENTIATION_HIGH
AC_VAN	FOCUS DIFF._HIGH	FOCUS DIFF_HIGH

Figure 8.5. Consistency Strategy Evaluation Results

The master relations for this alternative changed for higher aspiration levels compared to the previous analysis. That is why the generic accomplished strategy is at a lower level (Differentiation Medium, 76%) than for the previous analysis (Differentiation High, 72%). Table 8.22 presents the weighted percentage of expected measures to accomplish based on the evaluations performed and the input changes.

TABLE 8.22

CONSISTENCY STRATEGY EVALUATION RESULTS
(NEW PRODUCTS)

	MALLA	BARS	AC-VAN
Weighted % of key product MOP accomplished	68.0	93.0	93.0
Generic strategy (code)	10.0	4.0	10.0

	VALUE
Weighted % of key generic MOP accomplished	76.0
Generic strategy (code)	5.0

The firm is on the differentiation line according to the new mission definition.

3. The aggregate firm/demand analysis results (Table 8.23) show that the capacity added to the plant exploits the profitable market opportunities through time without meeting all demand requirements by the end of 1993.

TABLE 8.23

AGGREGATE FIRM DEMAND/SUPPLY ANALYSIS

	BILLET-N	BILLET-B	BILLET-A
1988	-21.0	-7.0	-8.0
1989	-21.3	-8.0	-8.0
1990	-19.0	-10.0	-9.0
1991	-15.0	-11.0	-10.0
1992	-13.0	-14.0	-11.0
1993	- 9.0	-19.0	-13.0
	RODS	WIRES LC	CABLES
1988	-19.0	-5.0	-7.0
1989	-19.0	-5.0	-7.0
1990	-17.0	-6.0	-7.0
1991	-14.0	-6.0	-7.0
1992	-12.0	-7.0	-7.0
1993	- 8.0	-8.0	-7.0

TABLE 8.24

MARGINAL REQUIREMENTS BY PROCESS AREA (TONS)
YEAR OF ANALYSIS : 1993
INFINITIE LOADING CAPACITY
(NEW PRODUCTS)

	1988	1989	1990
Iron Ore	- 74.8	- 75.3	- 78.1
Reduction Process	- 56.1	- 56.5	- 58.6
Electric Furnaces	- 74.5	- 74.9	- 77.7
Continuous Casting Machines	- 72.8	- 73.2	- 75.9
Rolling Mill	- 33.5	- 33.0	- 34.5
	1991	1992	1993
Iron Ore	- 76.8	- 80.0	- 85.6
Reduction Process	- 57.6	- 60.0	- 64.2
Electric Furnaces	- 76.3	- 79.5	- 84.9
Continuous Casting Machines	- 74.5	- 77.6	- 82.8
Rolling Mill	- 35.0	- 36.0	- 38.0

The required marginal capacity by process area to meet such extra demand is located in Table 8.24. The production by process area needed to meet the linear programming results appear in Table 8.25.

TABLE 8.25

PRODUCTION BY PROCESS AREA (TONS)
YEAR OF ANALYSIS: 1993
FINITE LOADING CAPACITY
(NEW PRODUCTS)

	BILLET-N	BILLET-B	BILLET-A
1988	420.0	130.0	145.0
1989	405.0	145.0	155.0
1990	370.0	185.0	165.0
1991	300.0	220.0	200.0
1992	250.0	280.0	220.0
1993	174.0	366.0	255.0

	RODS	WIRES LC	CABLES	MALLA
1988	378.0	100.0	125.0	10.0
1989	364.0	100.0	130.0	20.0
1990	333.0	120.0	135.0	28.0
1991	270.0	115.0	135.0	45.0
1992	225.0	135.0	140.0	70.0
1993	156.0	145.0	140.0	90.0

	TMIN	TFE	TAL	TBB	TPT
1988	705.9	529.4	702.8	687.0	625.5
1989	714.9	536.2	711.5	695.2	633.0
1990	732.1	549.0	728.2	711.3	647.5
1991	734.5	550.9	729.6	712.0	648.0
1992	768.7	576.6	762.9	744.0	677.0
1993	815.1	611.4	807.8	787.1	716.0

Chapter 7, Section 7.1.5, describes the models that are used to calculate such aggregate capacity requirements.

8.4.1 Summary

The marketing recommendation of the type of new products to manufacture is consistent with the generic business and manufacturing strategies intended after the manufacturing changes are implemented. The difference among the arbitrary target values for the different strategies is reflected on the closeness or distantness of the results of a consistency evaluation. It is very important, therefore, for the strategic planning committee to establish the set of strategies and its distinction through measures that permit a clear evaluation of the strategic choice.

Each evaluation module is intended to provide complementary information to other modules of the SMP-DSS.

8.5 Conclusions

The results presented in this chapter include the current assessment analysis of a steel firm, which confirms as mentioned before, the 1987 strategic choice of the firm. The actual alternative of change proposed by the firm was evaluated, confirming the aggregate expectations with regard to the firm's mission redefinition.

The application of the SMP-DSS to other manufacturing environments is as feasible as the one presented, given that the system basically performs the evaluation of strategic concerns through the comparison of targets and actual MOP calculated by the system. The advantage of having an identifiable function to calculate each relation, when different MOP and method of calculation are required, plus the flexibility to change the structure of the system, facilitate the implementation of other applications.

It is important to remark upon the importance of the auxiliary external models that provide information to the system (reference Chapter 7) and also, the interaction of the different departments in a firm to generate the required information. This involves the continuous feedback from tactical and operational planning levels to the strategic level (Figure 1.1), for the effective operation of the SMP-DSS.

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research was to incorporate strategic manufacturing planning in the strategic planning process of a business. Three goals were established in Chapter 4, that help to achieve this purpose. The conclusions resulting from this research are discussed in the context of these goals.

The first goal of this research was to develop a methodology for accomplishing strategic manufacturing planning which was consistent with the business strategy. This goal required the formulation of a strategic planning framework to include manufacturing in the strategic thought process. The major milestones to accomplish this goal are discussed in Chapter 5, which also presents a discussion of the vital elements and logical interrelationships which need to be considered. The framework proposed is the result of the integration and adaptation of several selected methodologies and techniques. The integration accomplished is considered to be a major contribution of this research.

The second goal and major thrust of the research was the development of a strategic manufacturing planning decision support system. The APL microcomputer based SMP-DSS was used as a research vehicle 1) to implement parts of the elements of the strategic planning framework; 2) to learn and structure basic ideas on how to integrate the complex interactions that occur in a firm, and 3) to evaluate a real situation based on specific criterion and measures of performance.

The model monitors and evaluates the effect that strategic manufacturing decisions have on the business. The considerations and limitations of the system are discussed in Chapter 7 and the appendixes. Each module of the system was verified to assure the correct operation and repeatability of the output results. The design of the SMP-DSS proved to be a very challenging experience that confirms how difficult it is to manage a firm. The SMP-DSS is a hierarchical modular structure. It permits the evaluation of the interaction of manufacturing decisions and each one of the following factors:

- Consistency with business objectives
- Competitive advantage
- Product/process matching
- Finance
- Capacity
- Market

based on the criteria or MOP selected under each factor.

The third goal was to apply the SMP-DSS to a real situation to verify the operations performed by the system and to validate it, by comparing the output of the system with the the current situation of the firm. It was used as a research vehicle to learn more about the way to evaluate strategic concerns.

It is the author's contention that a careful analysis and rationalization of the environment, the alternative generic strategies, and the manufacturing system should be carried out as an initial step, in order to adequately use the SMP-DSS.

It is important to remark that a model is only an approximation of the real system. Therefore, one should not speak of the absolute validity of a model, but rather of the degree to which the model responds in the same direction and desired magnitude as the real system under different conditions. This principle was verified with the example presented in Chapter 8.

9.1 Concluding Remarks

This research has developed an initial approach for accomplishing strategic manufacturing planning supported by a computer system designed to aid in the evaluation of a manufacturing strategy. There are immense possibilities for expansion. Future research areas could include:

1. The development of the logic to define and differentiate generic strategies and manufacturing MOP by type of industry, to create a generic data base of strategies that would be the basis of the master relations.
2. To expand the competitive advantage analysis module to include the analysis of more than one factor at a

time, by using an expanded simulation model, and the appropiate statistical procedures to incorporate these changes.

3. The development of other models to measure flexibility to compare with the current one available.
4. The development of the computer graphical representation of the results of the system.
5. To design a computer definition module and a translation module (post-processor), from which the SMP-DSS could extract the functional relationships that now exists explicitly defined in the functions of the system.

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