This is to certify that the

dissertation entitled

THE PRODUCTION PLAN IN AN MRP ENVIRONMENT
THEORY AND PRACTICE

presented by

Ronald Thomas Pannesi

has been accepted towards fulfillment
of the requirements for

Doctor of Philosophy degree in Production/Operations Management

Major professor

Date May 14, 1986

THE PRODUCTION PLAN IN AN MRP ENVIRONMENT

THEORY AND PRACTICE

By

Ronald Thomas Pannesi

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Management

1986

ABSTRACT

THE PRODUCTION PLAN IN AN MRP ENVIRONMENT
THEORY AND PRACTICE

By

Ronald Thomas Pannesi

The Production Plan in an MRP environment serves as an aggregate plan which sets the level of production for the firm, considering inventory/backlog objectives. The research investigated the relationship between production planning and MRP system success and examined the importance of the characteristics of the production plan itself. A survey questionnaire from 245 firms representing 97 industry codes was analyzed using the LISREL VI program of Joreskog and Sorbom. Results of the analysis supported the major hypothesis that those firms with a production plan outperformed those without. Further, there was strong support for the importance of the formality and regularity of forecasting and for the formality and regularity of production planning itself to the planning task. Somewhat less support was found for the importance of resource requirements planning and the participation of the major functions of the firm in production planning. In most all cases, the production plan was used in the formulation of the master production schedule. A final conclusion of the study was that MRP implementation cannot be considered complete and success of the system maximized, without the successful implementation and operation of the production plan.

To Ann

Without her patience and understanding
for the past 24 years of constant change,
this would not be possible. She endured.

ACKNOWLEDGMENTS

It has been said that completing a Ph.D. is impossible without help. This has nowhere been more evident than in the completion of this dissertation. So, to all those who have assisted me in this endeavor, my thanks. My thanks to Steve Chapman whose friendship, long standing association and endless hours of discussion helped me through the program from day one. Thanks to my committee, Dr. Lawrence Foster, Dr. Donald Taylor and to Dr. Richard Gonzalez whose comments were invaluable. My thanks to Marie Dumeney, who was secretary, confidant and friend, and who helped in many ways, especially in those last hectic days. Finally my undying gratitude to the Chairman of my Committee, Dr. Phillip L. Carter, who provided guidance from the first day of classes to the completion of the degree. His insights, leadership and above all, considerable efforts were absolutely essential to my success. I shall always be grateful.

TABLE OF CONTENTS

Page

LIST OF TABLES

TABLE		Page

LIST OF FIGURES

CHAPTER 1

OVERVIEW OF PLANNED RESEARCH

The concepts of Manufacturing Resource Planning as depicted by Wight (1981), have moved the practitioner toward a broader view of control of the manufacturing company. Although "closed loop MRP" as developed by Wight (1974) indicated the presence of a higher planning level (above the Master Production Schedule) called the Production Plan, it remained for the development of MRP II (Manufacturing Resource Planning) to demonstrate that the system should be tied into the highest levels of planning in the company. These highest levels have been variously identified as Business Planning (see for example Wight, 1981 and Schultz, 1981), Strategic Planning (see Van Dierdonck and Miller, 1981 and Hoyt, 1978) and Strategic Business Planning (see Krupp, 1982 and Pendleton, 1980). It is clear by examining these planning concepts that they have many common features and are often used interchangeably (Bacigalupo, 1982; Melnyk, Gonzalez and Anderson, 1983).

Strategic Planning, the highest level of company planning, has been generally defined as one of the elements or activities that constitute the larger concept of Strategic Management. Strategic planning can be described as top management planning which converts the goals of the firm into specfic plans dealing with markets, market niches and product offerings, considering both the external environment and internal strengths and weaknesses of the firm (Glueck and Jauch, 1984). Various models of the broader concept of Strategic Management have been widely disseminated (see for example Glueck, 1980 or Schendel and Hofer, 1979). There is general agreement in these models that strategic management has associated with it not only the tasks of planning, but also those of implementation and control. The literature also indicates that formal planning systems are integral to the linkage between planning formulation and implementation (Lorange, 1979). This is especially true of MRP systems.

Business planning, on the other hand, has usually been defined as a time phased statement of business revenues, expected profits, pro forma sources and uses of funds, etc. over a one or two year period (Berry, Vollmann and Whybark, 1979). Its purpose has been generally cited as providing the basis for information exchange with the financial community and for the preparation of internal budgets and the financial controls of the organization. Accordingly, it can be viewed as a planning activity which is derived from the Strategic Plan but may also be seen as establishing a financial framework for other plans.

Manufacturing Resource Planning and its central constituent element, Closed Loop MRP (Wight, 1981) provide the planning structure for both Strategic Planning and Business Planning execution and implementation. But Closed Loop MRP, even though the basic concepts have been around for quite some time (Plossl, 1980), has not enjoyed the success in implementation that one would have expected for such a comprehensive system. The reasons, of course, are many (Clark, 1982). There are, however, a number of companies which have achieved success defined as Class A status by Oliver Wight (Anderson, Schroeder, Tupy and White, 1978). For these companies, the next logical extention of their activities was to implement, or more particularly, evolve to Manufacturing Resource Planning.

It is interesting to note that while there are many software packages sold commercially that provide the basic structure and system for Closed Loop MRP implementation, there are virtually none that fully comprehend the Manufacturing Resource Planning activity (Landvater, 1979). This may be due to several reasons. Among these is the fact that the concepts are not fully understood by all (Andrew, 1979). In addition, the literature does not provide a common set of definitions of Manufacturing Resource Planning. An example of this is the confusion over the top level planning activity cited above.

Further, it is clear that even those companies which have been identified as successful users of Manufacturing Resource Planning do not share the same attributes, especially in the upper level planning function (Melnyk, Gonzalez and Anderson, 1983), and in any case certainly do not do planning in the way described by Wight and others (see for example Donkersloot, 1983 and Berry, Vollman and Whybark, 1979). Since, however, they are successful, it is clear that their planning functions above the Master Production Schedule are operational, are linked to Strategic and/or Business Planning, and are providing the needed information to the MPS which then drives the software oriented part of the system (see any MRP software package description such as AMAPS).

A critical planning element directly linking the Master Production Schedule (which drives the day to day operations of the system) and the top levels of planning in the company is the Production Plan.

In the case of the MRP firm, the production plan is a central mechanism in the implementation and control of those top level plans. In general, the production plan can be defined as an aggregate plan which is used to set the level of production activity and the attendant resources for the firm considering current and desired levels of inventory and the need to level the workforce (APICS Dictionary, 1984).

Numerous case studies have been done on the Production Plan and they constitute the bulk of the empirical production planning literature. These studies have focused on the relationship between the Production Plan and the Master Production Schedule, have identified the constituent elements of the Plan and have indicated their role in the system (see for example Berry, Vollmann and Whybark, 1979).

In addition, production planning in general and Hierarchical Production Planning in particular have been extensively studied and modeled in quantitative works which largely focused on the setting of production levels while trading off labor, inventory and capacity considerations while optimizing costs to the firm (see for example Holt et al., 1955).

The generalizability of these case studies is limited due to the restricted nature of their investigation. They may partially be seen as theory building. Consequently, further case studies, even undertaken on a grander scale, would add little to the testing of the ideas generated from past case studies. It is therefore proposed that a first cut at establishing stronger statistical relationships and theory testing be done.

Focus of The Proposed Research

Investigations into the entire planning process from strategic planning to Master Scheduling would be a large and complex process. While the ultimate goal of the researcher is to investigate those linkages and mechanisms in detail, initial efforts have been confined to providing a more comprehensive view of the importance of the various elements or features of the Production Plan and their relationship to the success of the firm in the MRP company (which represents a highly defined and structured environment). This research would then serve as a basis for further studies of the entire planning process in the manufacturing environment.

Accordingly, the focus of the current research is to provide, through survey means and subsequent statistical causal analysis, insights into the following two questions:

* Is the Production Plan related to success in an MRP company and if so how?

* Which elements of the Production Plan are important and how important?

Elements of the Production Plan

A consensus agreement on the elements/features of the Production Plan can be found in the empirical literature. Two works which encompass most of these points are those of Everdell and Ryde (1982) and Swoyer (1982). Some of the elements/features are objectives, others are procedural. Companies which have production plans which contain all of the following characteristics (or elements or attributes or features) should be more successful than those which do not. In addition, companies which have the characteristics discussed below and have them exhibited at a higher level (e.g., more formality in the planning activity) should be more successful than those which do not. The characteristics are:

* The production plan sets the overall level of manufacturing output.
* It is usually stated in terms of product families or similar aggregate terms.
* The main objectives of the plan include the control of inventory/backlog and stability of production.
* The plan covers a time horizon equal to or greater than the master production schedule.
* It is done regularly and formally.
* Marketing, manufacturing, finance, engineering and top management formulate the plan.
* It provides the basis for and is done in conjunction with resource planning, the highest level of capacity planning.
* It is management's authorization to the master scheduler and provides the limits for that schedule.

In essence, the production plan is the driving mechanism for the MRP system and provides top management with a coordinating and control mechanism which integrates MRP with the various other plans of the firm. It also provides the implementation mechanism for the orderly management of the resources of the manufacturing firm in support of the overall plans and goals of the company.

While each of the above characteristics is listed with apparent equal importance, investigation of actual practice may reveal different weightings. It is these relative weightings which the research hopes to explore.

Research Approach

The project calls for a survey to be sent to more than 2000 manufacturing firms throughout the U.S. Through a five part questionnaire (see Appendix A), it will gather information about the planning mechanisms of those firms. Initial analysis will be confined to those firms which have implemented or are currently implementing MRP systems. While major attention will be directed toward the Production Plan and its influence on the success of the system, additional data on Strategic Planning mechanisms will be gathered for follow-on research.

Sample Selection

As indicated above, the population is defined as those companies which are MRP users. Here, MRP is defined as "a system built around material requirements planning and also including the additional planning functions of Production Planning, Master Production Scheduling and Capacity Planning as well as the execution functions of Shop Floor Dispatching and Control and Purchasing Follow-up and Control" (APICS Dictionary, 1984).

Since a central factor in an MRP system is the software associated with material requirements planning, this characteristic may be used to identify MRP users through the customer lists of various software companies who specialize in MRP software. These lists will be acquired to assist in population identification. However, there are a number of firms who have developed their own MRP software in-house, especially those companies who were early adopters of MRP (Anderson et al., 1979). Such companies would not be included in the above customer lists. Further, such companies may likely have better developed, successful MRP systems since they were early adopters (Anderson et al.).

A second source for identification of the population in question may be found in the membership lists of the American Production and Inventory Control Society (APICS). APICS is generally credited with beginning the crusade for the adoption and popularization of MRP in the early 70's that continued through the decade (Plossl, 1980). The membership lists of this organization have been used in the past as a source of information for the study of MRP implementation practices (Anderson et al.).

A final source for identification of population membership is the mailing lists of the leading MRP consulting groups. This last group may capture some of the "home grown" software companies discussed above.

Sample Bias

There are a number of potential sources for sample bias. Principle among these are geographic location, industry type and respondent's knowledge.

In general, random sampling of companies from all the lists described above will insure that the sample is relatively free from most bias. However, APICS lists are not likely to be representative of all the areas of the country. Accordingly, the question becomes whether one area of the country is likely to produce information in some way different than another part. Or put another way, does MRP operate differently in one part of the country than another. While there is no conclusive evidence that such differences do not exist, it is highly unlikely that they do. Since the system is relatively universal, it can be expected that the variables that may differentiate one part of the country from another such as labor costs, proximity to transportation, energy costs, etc. have almost no influence on the operation of the MRP system. Therefore, even if the APICS lists are not representative of all areas of the country, little or no bias is introduced. Further, the consultant lists and the software vendor lists may represent a better cross section of the U.S. Random sampling from this list is also expected to reduce bias.

A more important issue may be bias introduced by differences in industry. While the Anderson et al. study (ibid.) showed no relationship between type of industry and performance, it may be that certain industries, in particular those which are repetitive in nature, may not perform as well since MRP is not particularly well suited to that environment (Maddox, 1984). The absence or presence of a production plan may well then be independent of MRP success. If sampling is done over a broad range of industries, such issues can be separated out to a certain extent and bias reduced.

Bias introduced by the respondent may easily be the most complex and difficult to control. There are numerous variables which must be addressed. These include lack of knowledge about the subject, fallibility of memory, cover-up, rationalization and repression (Simon, 1978). Of these, lack of knowledge about the subject may be the most likely in a survey and therefore may be the most damaging. The questionnaire must be answered by a person who is very familiar with the planning systems of the company to reduce this possibility. The materials manager would be the most likely person to have the required information. The questionnaire specifically addresses this issue by telling the recipient that the questionnaire should be answered by a person familiar with all planning systems of the company. If the recipient is not such a person, the instructions ask that the questionnaire be directed to such a person and suggest the materials manager as a likely respondent.

The remaining respondent bias issues are extremely difficult to control, but the questionnaire does have a number of internal validity checks in the form of questions which deal with consistency of information from section to section and within sections. Clearly, a determined respondent can confound the researcher as is always the case in survey research, but both the large size of the sample and the expected lack of motivation to do so should minimize those potentials and their effects.

The Model Under Consideration

As indicated above, the intent of the research is to investigate the relationships between the Production Plan and MRP success and to determine which various elements/features of the Plan are relatively more important to that success.

Accordingly, some measure of "success" must be made. Certainly, for any manufacturing control system to be deemed successful, customer delivery performance should be at a very high level. In addition this should not be achieved at the expense of excessive inventory levels. Finally, master schedule performance (the extent to which actual weekly production matches that which was planned by the Master Production Schedule is a key indicator of success. In the case of an MRP system, these three factors define a Class "A" system (Anderson et al., 1979 and Wight, 1974). The research does not attempt to define in an absolute way, what is good, bad or best but only seeks to compare levels in various companies and concludes that those firms which perform at a higher level are more successful than those which do not. The above three measures along with a self appraisal of class of MRP system are defined to be the dependent variables for the study and have been established as measures of "success."

The characteristics of the production plan stated above are the independent variables and can be conceptually grouped into three categories: plan characteristics or procedures (including such issues as the frequency and regularity of the plan formulation, participants in formulation, time horizon, etc.), resource planning (the existence of and details concerning resource requirements planning) and forecasting (the details surrounding the forecasting activity). All these are measured individually in a number of questions and taken with an overall measure of plan performance (percent of plan completed to schedule), constitute the variables which are the focus of the research. For the purposes of the study, they represent the measures of the endogenous latent variable, production plan.

Confounding the study are a number of other variables which can be considered exogenous to the model but which affect both the independent and dependent variables stated above. These variables fall into three categories: those which are associated with firm complexity (a latent exogenous variable) such as the number of people in the implementing facility and the total number of part and assembly numbers, those which are associated with product characteristics such as the master schedule horizon and its relationship to the lead time to manufacture the product (a latent endogenous variable) and those which are associated with MRP implementation success (a latent endogenous variable) such as length of time of implementation and progress achieved.

All of the above variables, dependent, independent and confounding and their proposed causal relationships are shown schematically in the path diagram of Figure 1-1. The central focus of the study, the influence of the production plan on success of the MRP system, is shown as the directional arrow from the production plan latent variable to the MRP system success latent variable. The remaining relationships between the latent variables are represented by the directionality of the arrows between the variables. Anderson et al. (ibid.) have established that the measures of the MRP system success variable are correlated among themselves.

Implementation time and the progress of implementation, the measures of implementation success have also been shown to influence the "success" of the MRP system (Anderson et al., ibid.) and in general, it has been established that the longer the firm has been at implementation the more successful the system. Implementation time is defined as the time from when the implementation project officially began until the time when it officially concluded. Sometimes, firms which have been uniformly unsuccessful over a period of time abandon the effort without officially concluding the project. This would then seem to indicate that the time/success relationship may not be linear. The Anderson study did not support that hypothesis, however. This may be because unsuccessful firms may have been non-respondents, not perceiving themselves as MRP companies.

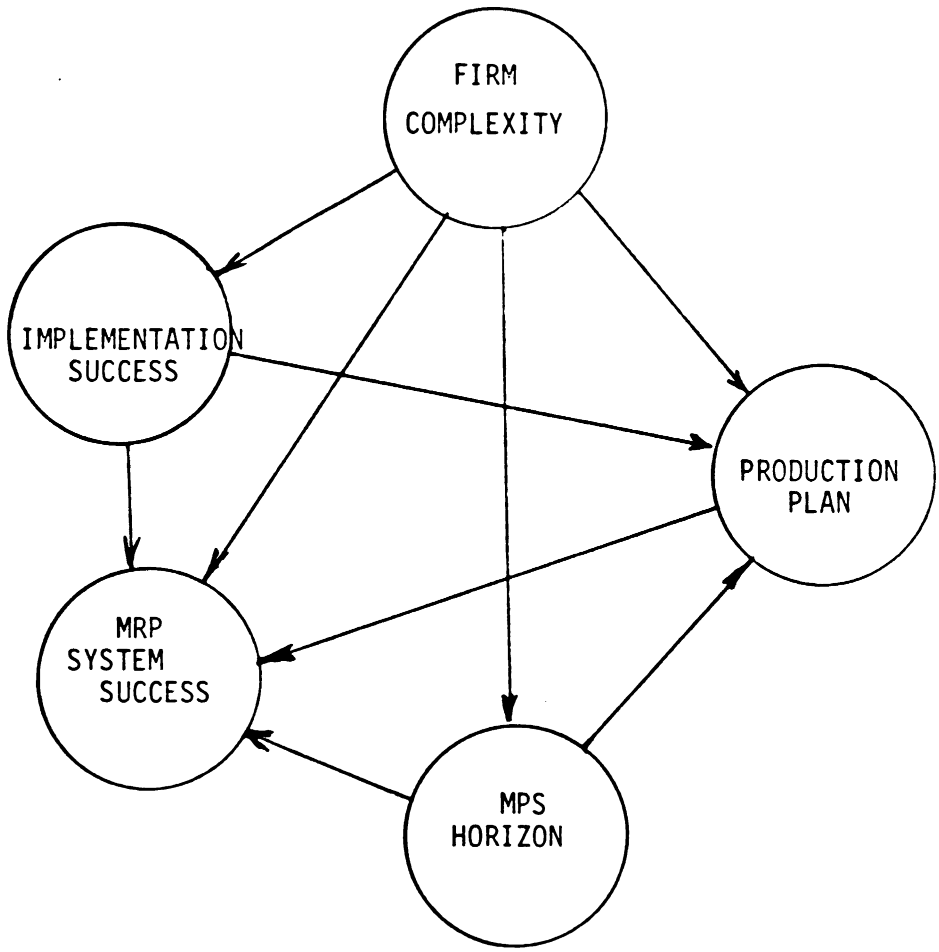

FIGURE 1-1

LATENT VARIABLE CONSTRUCT MODEL

Since the operation of the master production schedule requires information from a higher level, and since in most MRP systems much attention is given to the success of the master production schedule (Berry, Vollmann and Whybark), it can also be concluded that as implementation progressed, not only was the system likely to be more successful, but the company was more likely to have developed a Production Plan. Therefore, implementation time is confounding to the relationship under study.

In the case where the company has a product which has a long lead time and where the backlog extends far beyond that time, master production schedule performance may be achieved in the absence of a production plan. In such a case the MPS serves as a surrogate for the production plan.

The relationship between information flow and numbers of people in the information chain has been well developed by Galbraith (1973) and others. Also observed has been the relationship between product complexity and manufacturing operations (Hayes and Wheelwright, 1984). In both cases, increases in numbers of people and numbers of products respectively, strongly reduce the effectiveness of most system implementations. Thus, in these more complex environments we can expect that development of the various planning levels will be impeded and that MRP implementation success will be reduced. The exact nature of the reduction is not known. Thus, firm complexity is seen as a confounding variable.

Statistical Analysis

Since causal relationships are central to the study, the class of techniques referred to as causal analysis are appropriate statistical tools of analysis. The diagram in Figure 1-1 is structured similar to those commonly found in path analytic models with both direct and indirect paths of causal flow identified. But, since unidirectionality of causal flow, absence of measurement error, noncorrelation of residuals and errors and full identification of latent variables cannot be assured, the techniques of path analysis cannot be applied. In this case, it is appropriate to turn to a more generalized form of analysis of structural equation models, LISREL (Pedhazur, 1982). LISREL is based on maximum-likelihood statistical theory and provides the traditional outputs used to identify strength of relationships equivalent to beta weights in a regression model and the corresponding levels of confidence associated with each variable's weight. Central to the analysis is the definition of the structural equation model which analyzes the relationship between exogenous and endogenous variables and the measurement model which specifies the relations between unobserved and observed variables. In this case, the central relationship under consideration can be represented by the model of Figure 1-2.

Here, η represents system success and the y_i's are the variables used to measure success. Correspondingly, ε represents the Production Plan and x_i's the variables used to measure the Production Plan such as formality and regularity of planning, horizon of the plan, participants, frequency of planning, RRP, etc.). The δ's and ε's are the errors of measurement of the Production Plan and Success respectively. Many of the questionnaire responses will be combined to produce a uniform and more simplified measure of the variables.

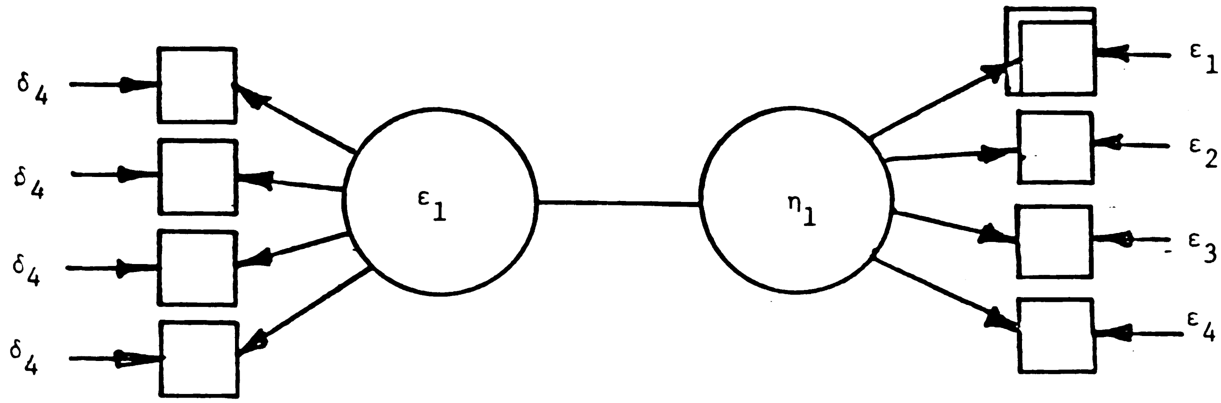

FIGURE 1-2
CENTRAL RELATIONSHIPS

Expected Results

A strong relationship is expected between the production plan and a highly successful MRP system. Further, since past case studies have shown the importance of certain production plan variables, strong support is expected for the causal relationship between system success and:

* Formality and Regularity of Plan formulation.

* Marketing, Manufacturing and Finance functional participation.

* Formality and Regularity of Forecasting.

* Resource Planning.

Weaker support for the causal relationships with the remaining variables is also likely.

While studies such as that done by Berry, Vollman and Whybark (1979) have indicated that frequency of Production Plan formulation/

review is usually monthly or quarterly, a more important factor is expected to be the regularity of such reviews. Regularity assures that smaller changes are more likely to be made than the large changes which cause major disruptions to the manufacturing environment. Also, formal meetings and formal output documents are believed to be important to overall system success.

The Berry, Vollmann and Whybark study also indicated that the most common principals involved in production plan formulation were marketing, manufacturing and materials and that only occasionally do other functions, such as finance, participate. This would imply that finance and the associated control mechanism, operating budgets, act as constraints rather than as participants in the formulation or review process. Further, this would imply that financial inputs (other than variance reports, etc.) are not normally re-examined except at annual intervals. However, in the more well run companies with successful MRP systems, finance should be an important participant in the production planning process. This is because the inputs of finance to the production plan which include an analysis of required money resources, impact on cash flow and the degree to which the plan meets the revenue objectives of the firm are very important in plan formulation or review.

One of the major reasons to do production planning is to control the inventories/backlogs of the firm. Certainly, one measure of plan success and of MRP success is the extent to which master schedule and customer delivery objectives are met while inventories or backlogs are held in check. The central role of the production plan is expected to be critical to the success of the MRP system.

Finally, resurce planning, the highest level of capacity planning has always been an important issue in aggregate planning. Thus, there is ample reason to believe that resource planning will be strongly associated with the success of the MRP system.

Conclusion

If the study should support the relationships above or even if it should show that the above relationships are different from those expected, this would provide significant information about the aggregate planning mechanism. The study should initiate new theory and define new research directions for the aggregate planning function in an MRP environment. The study should also provide the foundation for future research that links all the planning mechanisms from the Strategic Plan to the Shop Floor in an MRP environment. Finally, the study may be the start of generalized research on the same issues in non-MRP environments.

CHAPTER 2

LITERATURE REVIEW

"Production Planning--the function of setting the overall level of manufacturing output. It's prime purpose is to establish production rates that will achieve management's objective in terms of raising or lowering inventories or backlogs, while usually attempting to keep the production force relatively stable. The production plan is usually stated in broad terms (e.g., product groupings, families of products). It must extend through a planning horizon sufficient to plan the labor, equipment, facilities, material and finances required to accomplish the production plan. Various units of measure are used by different companies to express the plan such as standard hours, tonnage, labor operators, units, pieces, dollars, etc. As this plan affects all company functions, it is normally prepared with information from marketing, manufacturing, engineering, finance, materials, etc. In turn, the production plan becomes management's authorization for the Master Scheduler to convert into a more detailed plan" (APICS Dictionary, 1985). "Production Plan--the agreed upon strategy that comes from the production planning function" (APICS Dictionary, 1985).

"The purpose of the production plan is to give management a broad planning handle that is more relevant than simply planning in dollars, but that shows the big picture far better than planning by part number" (Wight, 1981).

Background

The arena of Production and Operations Management has seen a virtual explosion of ideas, techniques and concepts over the past decade and a half. Among these are Material Requirements Planning, Manufacturing Resource Planning, Computer Aided Design, Computer Aided Manufacturing, Computer Integrated Manufacturing, Group Technology, Flexible Manufacturing Systems, Just-in-Time, Robotics and others.

Certainly a great deal has been written about Material Requirements Planning and its generic parent Manufacturing Resource Planning (MRP II). (For a good summary of the development and evolution of MRP, see Plossl, 1980.) There are now scores of Software suppliers who sell MRP software. Software has been developed not only for mainframes (e.g., Software International or COMSERV) but also for minicomputers (IBM's Manufacturing and Accounting Production and Inventory Control System) and even microcomputers (Micro-MRP). The use of MRP has become widespread. IBM alone has sold over 10,000 licenses for the use of its MRP software (Grey, 1986). Given its widespread usage, one would expect a high degree of success in industry. Such has not been the case as reported by Anderson et al. in 1981. Certainly, the technical details of the system have had considerable exposure (see for example Wemmerlov, 1979, or the published checklists by Garwood, 1977 and by Wight, 1977). Most often, system failures are attributed to lack of management support and involvement and/or poor employee attitudes toward the system (Hall and Vollmann, 1978 or Pannesi, 1983 or Wacker and Hills, 1977).

But top management usually participates in manufacturing planning and control systems only at the upper levels of the planning activities. For an MRP system, these upper levels have been identified as Business Planning and Production Planning by Wight and others (Wight, ibid., Chapter 3 and Melnyk, Gonzalez and Anderson, 1983). These upper levels of planning are important to the overall success of the system. But how important and in what way? This study will investigate the above questions as specifically applied to the Production Plan defined at the beginning of this chapter.

Production Planning

Before dealing with these questions directly, it would be well to investigate the nature of these planning activities and define their role in the system. Also, the relationship between material requirements planning, "Closed Loop MRP" and Manufacturing Resource Planning (used synonymously with MRP II in this study) should be defined. Difficulties with these terms have arisen frequently in the literature. For purposes of this study, material requirements planning is defined as "A set of techniques which uses bills of material, inventory data and the master production schedule to calculate requirements for materials...it is thought of as primarily a scheduling technique, i.e., a method for establishing and maintaining valid due dates on orders" (APICS Dictionary, ibid., p. 18). Closed Loop MRP can be defined as "A system built around material requirements planning and also including the additional planning functions of production planning, master production scheduling, and capacity requirements planning." It also includes the execution functions of shop floor control including "Input-Output measurement, detailed Scheduling and Dispatching, plus Anticipated Delay Reports from both the shop floor and vendors, Purchasing Follow-up and Control, etc. The term "closed loop" implies that not only is each of these elements included in the overall system but also that there is feedback from the execution functions so that the planning can be kept valid at all times." (APICS Dictionary, ibid., p. 5.) See Figure 2-1 for a diagram of Closed-loop MRP. Manufacturing Resource Planning (MRP II) is "A method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has a simulation capability to answer "what if" questions. It is made up of a variety of functions, each linked together: Business Planning, Production Planning, Master Production Scheduling, Material Requirements Planning, Capacity Requirements Planning and the execution support systems for capacity and material. Output from these systems would be integrated with financial reports such as the business plan, purchase commitment report, shipping budget, inventory projections in dollars, etc. Manufacturing Resource Planning is a direct outgrowth and extension of closed-loop MRP." (APICS Dictionary, ibid., p. 18.) See figure 2-2 for a diagram of Manufacturing Resource Planning.

Strategic Planning

We can additionally identify a higher level of planning, Strategic Planning. Strategic Planning is currently thought of as part of the broader concept of Strategic Management. Strategic management has been defined by a number of authors (see for example, Glueck and Jauch, 1984). Further, strategic management comprises a number of tasks. These include 1) goal formulation; 2) environmental analysis;

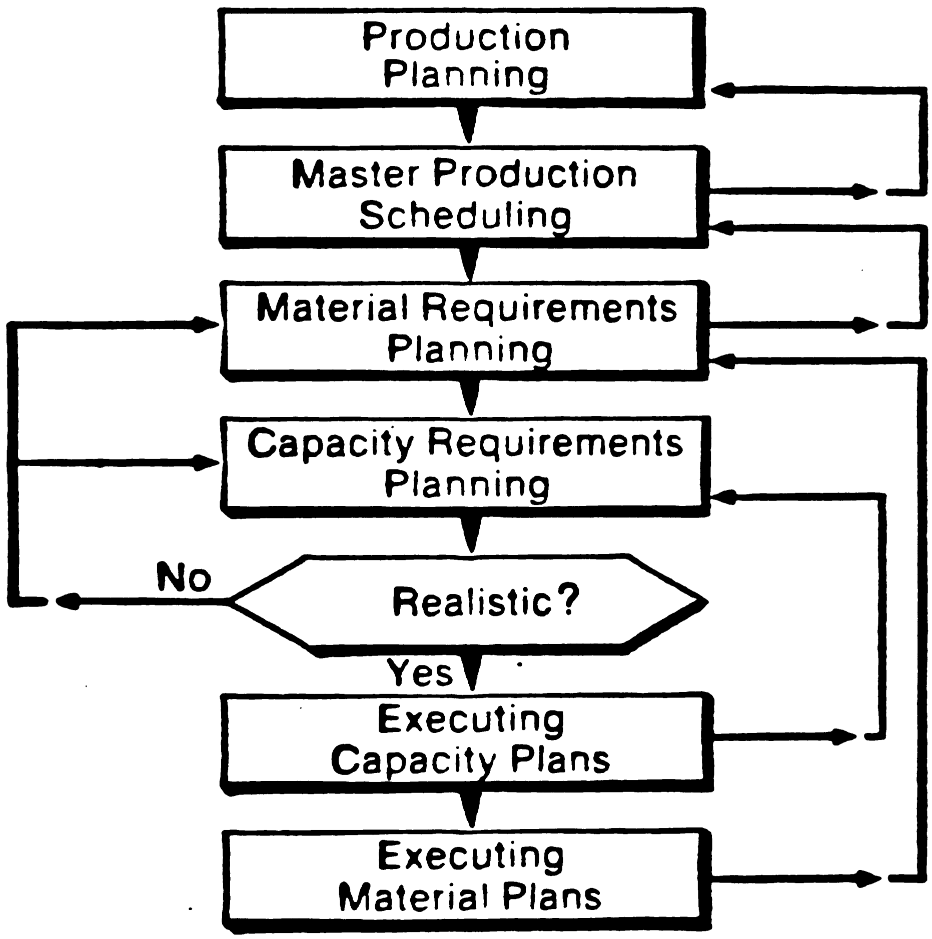

FIGURE 2-1

"CLOSED LOOP" MRP MODEL

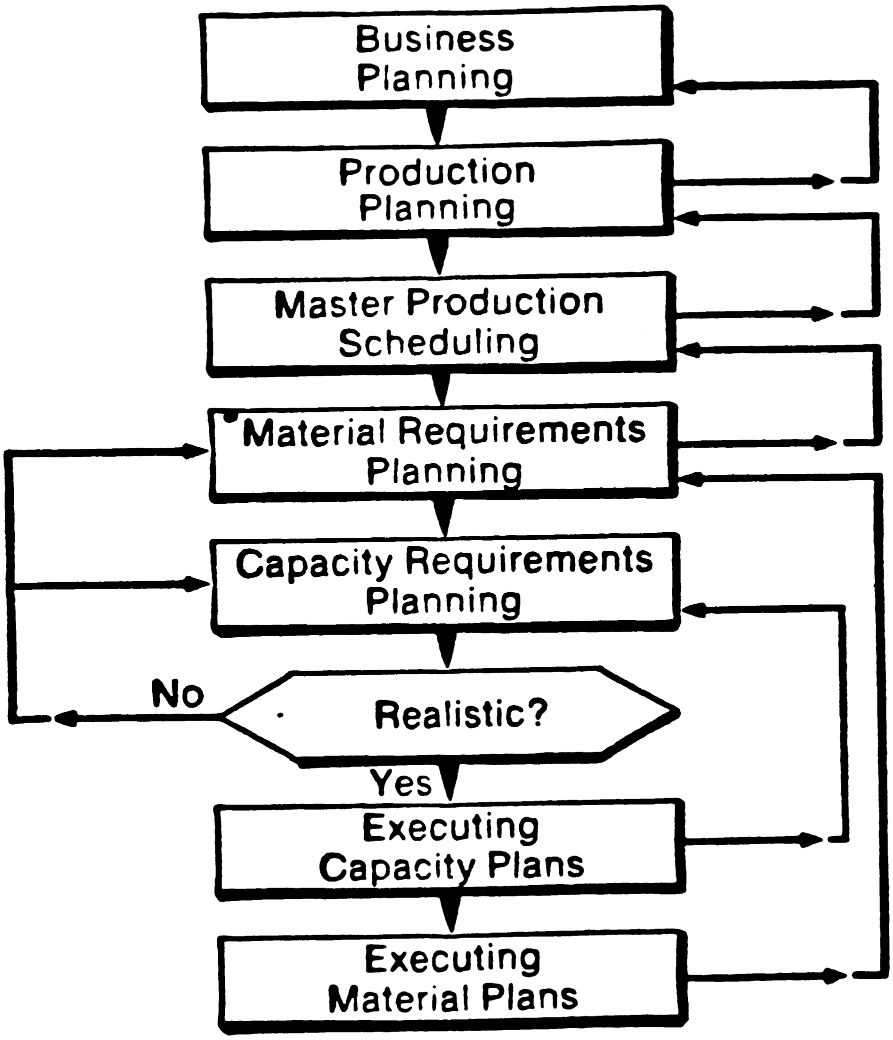

FIGURE 2-2

MANUFACTURING RESOURCE PLANNING MODEL

3) strategy formulation; 4) strategy evaluation; 5) strategy implementation; and 6) strategic control (Schendel and Hofer, 1979). The relationship between MRP II and Strategic Management has begun to be explored recently and in some cases, confusion has arisen between business planning and strategic planning and often the terms are used interchangeably (see for example Melnyk et al., ibid. and Bacigalupo, 1982). In other cases, strategic planning is directly identified as the highest level of planning for an MRP II company (Van Dierdonck and Miller, 1980 or Hoyt, 1978, pp. 472-480). In at least two cases, it is referred to as Strategic Business Planning (Krupp, 1982 and Pendleton, 1980). For the purposes of this study, we will differentiate between strategic planning and business planning. The Business Plan is defined as "A statement of income projections, costs and profits usually accompanied by budgets and a projected balance sheet as well as a cash flow (source and application of funds) statement. It is usually stated in terms of dollars only. The business plan and the production plan, although stated in different terms, should be in agreement with each other." (APICS Dictionary, ibid., p. 4.) A graphical representation of the interaction of strategic planning, business planning and production planning is found in Figure 2-3.

Production Plan Issues

The information above and that given in Chapter 1 serves to identify the critical issues which were considered in the remainder of the literature review. The review will focus on the characteristics of the production plan which have been identified. These are:

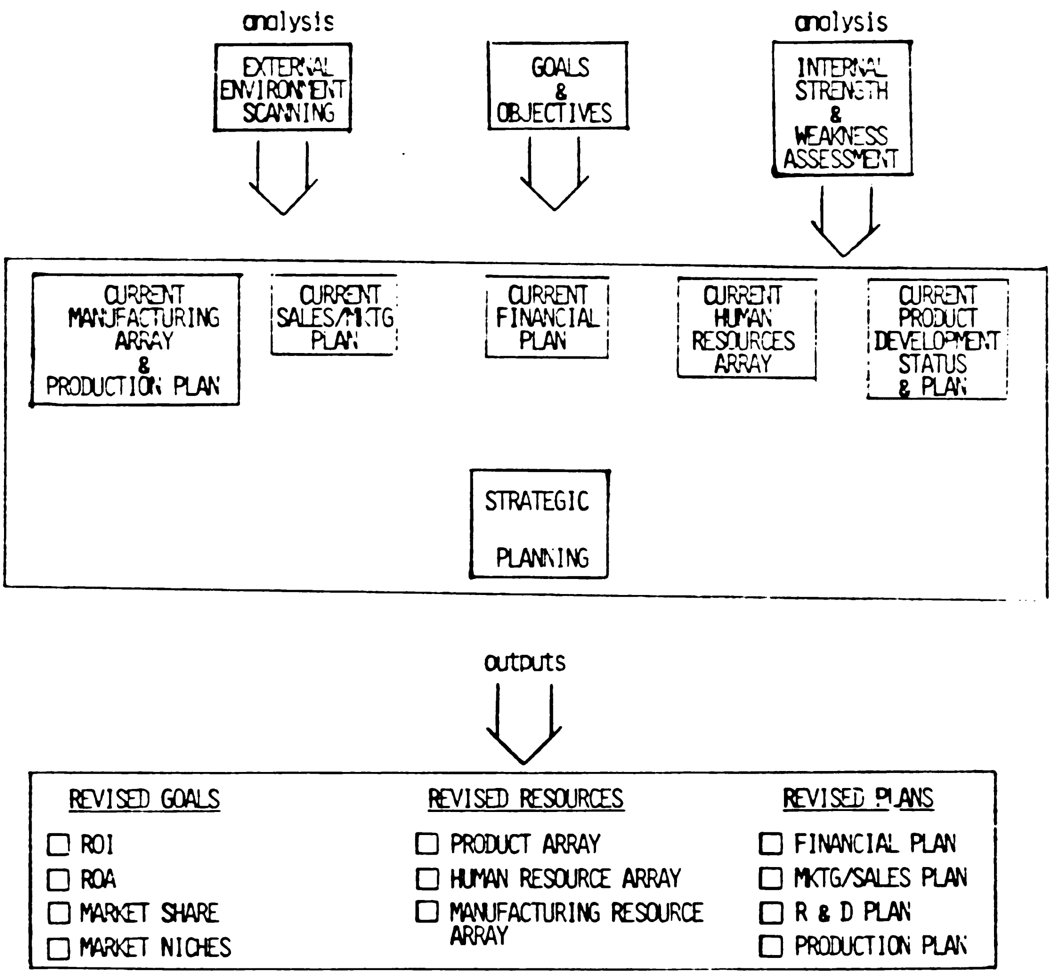

FIGURE 2-3

CONCEPTUAL VIEW OF THE RELATIONSHIP
OF THE PRODUCTION PLAN
TO THE STRATEGIC PLANNING ACTIVITY

* Setting the level of production
* Production plan units
* Formality and regularity of planning
* Forecast issues
* Use of the plan in lower level planning
* Relationships to higher level planning
* Plan participants
* Resource (capacity) issues

For convenience, the following review will be done chronologically.

Hierarchical Planning

It should be clear from the above discussion and by consideration of Figure 2-3, that these planning systems are hierarchical in nature. The notion of a hierarchy of planning and the tasks associated with each level is certainly not new. Perhaps one of the better models created to describe this concept was presented by Andrews (1961). In the case of production planning (used generically here), there have been a number of studies devoted to the hierarchical planning process. Perhaps the watershed work was done by Holt, Modigliani, Muth and Simon (1955) who looked at the single facility, single product aggregate planning problem. The HMMS decision rule (as it has come to be known) dealt with production smoothing considering four cost factors: regular production costs, costs of hiring and firing, cost of overtime and cost of inventory. A total cost function was proposed and the problem was to find the values of P (the production in period t) and W (the size of the workforce in period t) that would minimize the total cost function. The cost function was expressed as a quadratic. The study was done using the example of a paint factory. In the study, production planning was carried out on a monthly basis and forecasts were available for twelve months. Among other findings it was noted later by Eilon (1975) that a comparison of the HMMS rules for alternative forecasting procedures with the hypothetical case of perfect forecasts provides an indication of the desirability of improving forecasting in any given situation. The criticisms of the HMMS model are mostly concerned with the appropriateness of the cost function. For the purposes of this study however, it is more appropriate to simply note that aggregate planning as seen by HMMS focuses on reduction of costs, smoothing of production and control of inventory. These issues are part of production planning as indicated earlier. Thus, the production plan is used to set a smoothed rate of production for the firm.

As indicated above, the HMMS model was a watershed since from it sprang a number of other studies of the aggregate production planning problem. The literature in this area is selectively reviewed to point out those studies which can be considered meaningful to the problem at hand and to compare these works to that of the empirical literature.

Other approaches to the aggregate production planning problem followed the HMMS work. Notable among these is the work of Curtis Jones (1967). Jones indicated that the mathematical optimizing techniques have not been adopted by industry for aggregate production and work force decisions (ibid., p. 844). To overcome this problem, Jones developed a heuristic approach that postulated the existence of two linear feedback rules, one dealing with workforce levels and the other with production rates. The program searched for the set of parameters which gave the lowest cost over time to the particular firm where it is being applied. An advantage to this technique is that any cost function can be used (making it applicable to any firm which can define its cost function; not an easy task). The disadvantage is that an optimal solution is not guaranteed as is the case with the HMMS model. In the MRP II case, there is no formal optimization of costs in the production planning phase but the plan addresses the same issues in resource planning and production rate setting.

Another approach to the aggregate scheduling problem was provided by Taubert (1968). Taubert proposed a search decision rule (SDR) approach to the aggregate scheduling problem. Taubert also cited the low adoption rate of previous models in industry and noted that the closer that mathematical models approach the realistic manufacturing environment, the higher the model complexity and the less likely its use (p. B-343). Taubert's model dealt with a wider scope than the traditional analytic/optimal decision approach. His model also considered non-linear and discontinuous costs, constraints on capital and overtime, multiple products and the use of subcontracting to relieve capacity constraints. In the MRP II model, resource constraints are considered at three levels: resource requirements planning at the production plan level; rough cut capacity planning at the master production schedule level and capacity requirements planning at the material requirements planning level. Constraints on capital are considered by finance in the resource planning activity. These and related issues will be discussed at length later. Taubert applied a specific pattern search to locate the minimum value of the objective cost function and the results were favorably compared to the HMMS paint factory problem.

A different approach was taken by Deziel and Eilon (1967). In this approach, it is not the cost function that was sought to be minimized, but the fluctuations in production and inventory levels. This is a fundamental goal of the production plan in the MRP II system but is not usually handled in a formal manner such as that advocated by Dezial and Eilon. Work force levels were also maintained as constant. The model does take production lead time into consideration but only incorporates the demand forecast for the next period but not for all subsequent periods. Because of these shortcomings, the adoption of the model in industrial situations is likely to be somewhat limited. The production plan in the MRP II system extends over a time horizon sufficient to acquire all resources necessary to execute the plan as stated earlier.

One method which attempts to model the behavior of a manager in making production planning decisions was proposed by Bowman (1963). Referred to as the Management Coefficients Approach, the model sought to describe management's decision making behavior in a given environment. Several statistical regression equations to capture the scheduling rules used by management were constructed from actual management situations. These equations deal with work force, forecast of demand and inventory levels much the same way that the models reviewed above did. Success with the model was limited and criticisms great. The model has not found great popularity in the industrial environment but it did represent an important attempt to integrate practitioner technologies with that of mathematical modeling.

Other aspects of aggregate production planning were also studied during the early 70's before the classic works of Bitran and Hax which moved the consideration of aggregate planning to the next level of evolution. Three of these studies are worthy of note. All three are the works of Moskowitz or Ebert.

Moskowitz (1972), sought to investigate the effects of forecast reliability and forecast horizon on human aggregate planning decisions as compared to those of linear decision rules (LDRs). To some extent this represented research in the same spirit as that of Bowman. Again citing the fact that previous LDRs have not been accepted by practicing managers, Moskowitz used a group of "experienced" graduate students under controlled conditions to make aggregate production decisions and compared the results to those of an LDR. While the results showed that the LDR was superior to the performance of the graduate surrogate production managers, there were other findings of interest. Under increasing forecast uncertainty, subjects placed more emphasis on workforce size and discounted forecast implications, often implicitly extending previous forecasts where accuracies were known. This finding is consistent with many managers who, forced to make decisions without good information, must either provide protection through increased capacity or do their own kind of "forecasting." The production plan in an MRP II system depends on a forecast for its initial information to initiate the planning process. Due to the shortcomings of the experiment, it was difficult to conclude much else.

Ebert (1972) also dealt with human vs. mathematical model performance in aggregate planning. In this study, time-horizon complexity (frequency and number of decisions to be made for the future) was examined. Intuitive manager decisions were compared with the HMMS model performance. The most important conclusions were that as time horizons increased or as the number and kinds of decisions increased, intuitive performance decreased. The production plan in an MRP II environment regulates change to the plan and formally evaluates plan performance each time the plan is reviewed. Unfortunately, Ebert's study could not determine when (how far into the future) a mathematical model should replace human intuition.

Somewhat later in 1976, Ebert dealt with another aspect of the aggregate production smoothing problem. In this case Ebert studied productivity changes over time due to learning curve effects and how this affected the aggregate planning model. The production plan in an MRP II environment does not directly deal with these issues in a formal manner and can be somewhat criticized for not doing so. The study used the Hooke-Jeeves direct computer search approach (1961) to set and optimize production levels and had, as its goal, minimum costs associated with productivity changes due to learning effects, target ending inventories, smoothed production and some estimates of cash flow. Cost structure and demand-forecast inputs were the same as those of the HMMS model and therefore afforded a direct comparison. Even though the Hooke-Jeeves computational method did not guarantee an optimal solution but only an approximate one, some interesting results were obtained from the analysis. When an 80 percent learning curve was compared to a 90 percent learning curve, it was clear that in the case of the slower learning curve demand fluctuations were absorbed more by inventory buildups and less by productivity changes. The model demonstrated the capability of providing a near optimal plan for hiring and layoffs since in the case of the 90 percent learning curve more had to be done to accommodate demand changes and the analysis clearly provided timing information on this need. The ability to provide cash flow information was another benefit of the model. Of course, this analysis was only as good as the cost functions which were quadratic (per HMMS). Finally the model was very sensitive to errors in initial productivity estimates and once again points up the need for good estimates of cost and productivity information in any aggregate smoothing model. Learning curve information is not directly considered in the production plan model in an MRP II system. In general, productivity is assumed to be a constant for any given plan.

Next in the sequence of works on the aggregate planning issue are the studies of Bitran, Hax and Meal. Their work is particularly significant because it addresses various levels of hierarchical planning and can be compared to the levels of planning in an MRP II system. Hax and Meal introduced three levels of planning with particular characteristics identified for each level (1975). These levels were meant to be synonymous with the product structure. They were:

Items - final products delivered to the customer.

Families - groups of items that share a common manufacturing set-up cost.

Types - groups of families whose production quantities are to be determined by the production plan. These groups of families usually have similar costs per unit of production time and similar seasonal demand pattern.

In an MRP system, the item level is dealt with by the master production schedule and the family level is considered in the production plan without the restriction of commonality of set-up cost.

In a subsequent work of far greater detail, the design of hierarchical production planning (HPP) systems was refined and the interactions between hierarchical levels was fully discussed by Bitran and Hax (1977). After recognizing the three levels of aggregation and the sequential nature of the planning process from level to level, the methodology proceeded from the highest level (type) by allocating capacity among types according to demand, optimizing cost and then disaggregating to each lower level in turn. At each level, holding costs and overtime costs are used as tradeoffs during the optimization. For convenience, disaggregation was done for the first period only at each level. This is because of uncertainty of demand in the horizon and because data collection and processing was reduced considerably by dealing with only one period. The procedure is consistent with other aggregate models discussed above. The time frame considered by the model is one year or one seasonal cycle whichever was longer. In the model proposed by the authors the time frame is the same for both conditions. The model also considered the effect of production lead time on the horizon of the aggregate plan. Changes within the production lead time were prohibited. This is similar to rules associated with freezing the master production schedule and production plan which are part of the rules surrounding the production planning process in an MRP environment. The condition for disaggregation used in the model was that the sum of the production of the families in a product type and the amount dictated by the higher level for this type be equal. This is similar to the general rule in MRP that the sum of the master production schedule equal the production plan.

The overall model was tested on a manufacturer of rubber tires. The model was run for a full year and production decisions were made every four weeks. A number of runs were made to test various effects. The cost and size of backorders increased as forecast error grew but even up to 30 percent error, the system was able to provide decisions consistent with a 97 percent service level. More importantly, the runs showed that accurate forecasts are easier to obtain at the aggregate level than at the levels below it. This was seen as an important justification for the hierarchical approach. This thinking may also be applied to the production plan in an MRP II system.

The original HPP work led to other studies on HPP issues. Many of these were reviewed by Krajewski and Ritzman (1977). The authors identified the importance of this problem and supported the contention that real world problems are sufficiently complex to warrant a hierarchical and sequential approach. They further identified the second level in the hierarchy as the "Master Schedule Level" obtained from the disaggregation of the highest aggregate production plan. On the manufacturing side, they identified complexity from single product, single stage to multiple products, nonlinear assembly tree, multistage systems. In discussing this last, most complex problem, the authors indicated that at the time of writing, problems of practical size of this type were computationally unfeasible. They cited material requirements planning as a practical alternative to solving this set of problems. The authors proposed a general mathematical programming model (General Disaggregate Model [GDM]), (ibid., p. 2) with which to compare research reported on disaggregation. The model was intended to deal with three stages of disaggregation; final product quantities from aggregate decisions on output and capacity; timing and sizing of manufactured (or purchased) component quantities from timing and sizing of final product quantities; and the short term sequences and priorities for the jobs (orders) and machine (or other resource) allocation given the timing and sizing of manufactured (or purchased) components. The model is applied to service operations as well as manufacturing operations. The levels defined in the study are the MRP II equivalent of production plan to master schedule to material requirements plan to sequencing and dispatching activities on the shop floor. The methods and studies selected by the authors for comparison are not reviewed here. One comment worthy of note is that aggregate capacity decisions are made in some models at the production plan level and in others at the next level down (end product level). This, as noted later, is consistent with practice in MRP II systems in industry today.

Much of the research mentioned above, deals with time horizons of aggregate production planning by simply stating a particular period (usually multiperiods) or uses periods established in previous works (see for example, Jones, ibid., p. 852). McClain and Thomas, however, provided research on the effects of horizon length on aggregate planning (McClain and Thomas, 1977). This is to a certain extent an extention of Ebert's work discussed above (ibid.) in that, the discussion on ending conditions can be used in conjunction with the Ebert study to augment human judgment. Kunreuther and Morton defined a "natural planning horizon" where model consideration of additional periods in the horizon would not affect the optimality of the first few planning periods previously calculated. McClain and Thomas pointed out that natural planning horizons do not always exist especially when the very general assumptions of Kunreuther and Morton are specified differently. This is particularly true of the cost function and the inclusion of marginal costs in the analysis. McClain and Thomas proposed a linear programming (LP) formulation which would directly determine end conditions and which would assure good performance of the planning model in the absence of a natural planning horizon. They have used a no-trend, seasonal demand pattern for the analysis. A simulation test for various conditions of the model was performed and several optimal horizon lengths for the various conditions were found. To extend Ebert's work, the establishment of steady state ending conditions could give management a much better way to summarize future requirements rather than add more periods to the decision problem. Further McLain and Thomas felt that "short horizon models with good ending conditions are likely to be easy for managers to understand and accept, because these models operate in a manner analogous to that of the manager" (ibid., p. 736).

The above approach can be compared to the production plan of MRP II where the time horizon is understood to be greater than or equal to the cumulative lead time for the acquisition of resources specified by the plan. A time horizon of this length is needed because, resource requirements planning which considers the acquisition of all resources needed to execute the plan, is done in conjunction with the production plan as a first cut at capacity planning (Njus, 1983). In addition to the above, the production plan and resource plan are often used to generate a variety of subplans such as the manpower plan, a facilities plan, an energy plan or cash flow projections (Everdell and Ryde, 1982). Some firms extend the resource plan as far into the future as five years (see for example the Hyster Case in Berry, Vollman and Whybark, 1979).

Returning to other studies using mathematical models to research the aggregate production planning (smoothing) problem, Mellichamp and Love (1978) also noted that mathematical models have not gained wide acceptance in actual planning situations. As a solution to this problem, the authors suggested a modified random walk production-inventory heuristic for the problem. Like most other models, a demand forecast was given for each period in the horizon and the model determined production levels, work force levels and inventory levels which minimize the costs to the hypothetical firm. To illustrate the effectiveness of the model the heuristic was applied to four variations of two production situations described in the literature; the ubiquitous HMMS model and hypothetical Company X, described by Jones (ibid.). In both cases the heuristic compared favorably to the optimal performance of the other models (less than 2% increases in overall costs were observed (ibid., p. 1249). The authors claimed that the advantages of the Heuristic over the optimal models was the minimum amount of period to period adjustment in production, workforce, etc. that the model produced when compared to the older methods. In addition, the approach was said to be sufficiently flexible to incorporate most cost functions found in practice. However, perhaps the most telling remark made in the study was, "Since the clear verdict on aggregate production planning methods is that they are not enjoying wide use in industry, the implication is that many firms are not pursuing optimal scheduling policies" (ibid., p. 1250). The production plan in the MRP II system does not directly deal with cost optimization.

Another interesting aspect of hierarchical production planning which is also not addressed by the production plan in an MRP II situation was studied by Axsater (1981). The study investigated the aggregating logic and addressed the question of how to aggregate data for use in aggregate production planning. Specifically, the paper addressed the aggregation of future demand, the use of a bill of materials and the role of capacity requirements. There appears to be no specific parallel advise for aggregation of products in the MRP II equivalent production plan other than to aggregate by family (see the definition at the beginning of the chapter). However, there is equivalence between the Axsater bill of material and capacity rules and those found in MRP II. Axsater developed a series of mathematical formulations for solution to the problem but solutions were not applied to practical problems for demonstration. Accordingly, the formulations may suffer the same fate as a number of other aggregate planning models have and that is lack of adoption by industry.

Returning to the hierarchical production planning models discussed earlier, Bitran, Haas and Hax extended earlier works in two studies of significance (1981 and 1982). In the 1981 paper, the authors revised and improved the methodology of the earlier 1977 Bitran and Hax work (ibid.). The levels of aggregation were the same as those originally stated by Hax and Meal above. Their model now accepted any form of mathematical model to represent the aggregate (highest) stage rather than just the previously used LP model. The disaggregation of the highest level is still just confined to the first period due to demand uncertainties in the planning process. The principle changes made by the authors were to revise the regular knapsack method used in disaggregation to accommodate a look ahead feature that relaxed the equalization of run-out times previously required by the model. In addition, the model was altered to allow for high set-up costs where the model previously had shown limitations (ibid.). The resulting model was run using the rubber tire manufacturer model used previously (ibid.). The performance of the model when compared to previous models and to a mixed integer based model performed extremely favorably. To a large extent, this adjusted model is far more suitable for real life problems than were many other previous models because of its greater flexibility.

The 1982 work was particularly significant because it extended the previous model to a two stage system and the work was compared to an MRP II system. The authors likened the two stage system to an environment involving fabrication and assembly operations. The approach addressed both levels jointly, thus guaranteeing the appropriate coordination of the two-stage process. The model reconciled possible differences at the detail level of adjusting part inventories (p. 234). The model operates quite similarly to the MRP II model which starts by informally aggregating finished products into families to form the items in the production plan, then disaggregates the resultant plan into finished products at the master production schedule level which then drives material requirements planning to generate detailed part and assembly schedules.

Like MRP II, the authors called for managerial action at each stage of the HPP process, although, in MRP II the results of the material requirements planning activity are highly formalized and require less managerial interaction. In the study, the highest level of the aggregation was handled via an LP formulation but the authors acknowledged that any number of alternate models may be used. Like MRP their model netted inventory against demand before proceeding with scheduling. The model also dealt with uncertainty of demand for products and parts through the use of safety stock again possible through MRP II. At the disaggregation step, the model disaggregated the finished product schedule and parts schedule separately. In the MRP II model, such disaggregation would be done only through the bill of materials for the finished items unless there were parts or assemblies planned at the master schedule level. Probably one of the most interesting points is that in comparing the HPP model to MRP II, the MRP II system is represented from the master production schedule down only! This may be because the authors were interested only in the computational aspects of MRP II and did not recognize the production plan as defined earlier as a computational part of the system. Most software suppliers would agree. The authors specifically cited "the lack of an appropriate support for managers to generate a good master schedule" (p. 242). This ignores the existence and role of the production plan although it had been well defined and discussed in the literature at the time of the study under consideration. Part of the MRP II model presented by the authors is the capacity planning capability of the model. This led the authors to describe the MRP model as "...a simulation tool which allows managers to test some suggested production programs and identify their consequences" (p. 243). In order to compare their version of the MRP system with the HPP model proposed in the study, the MRP system was modeled with a one stage HPP to determine aggregate assembly scheduling for finished products driving detailed finished product planning which in turn drives the master schedule. The master schedule was in effect determined by disaggregation of the solution of an aggregate LP model for product types for the full planning horizon. The disaggregation procedure called for the equalization of run out time per the 1981 work just discussed. Part time schedules after disaggregation were determined using the Silver-Meal algorithm. The test was run and the robustness of both the HPP and MRP model (as specified by the authors) was determined by evaluating costs and backorders for the two models under varying finished product capacity, part capacity, forecast errors, seasonality of demand, finished product setup costs, part setup costs, part holding costs, seasonality of finished product demand and overtime costs. When total costs were used as a measure of performance, 93 percent of the tests favored HPP over the MRP system. Using total backorders as a measure, 73 percent of the tests resulted in no backorders under either methodology but 22 percent of the tests favored HPP.

After extensive testing, the authors determined the conditions under which MRP outperformed HPP. All comparisons were done in terms of total costs. MRP outperformed HPP only when capacity was unlimited, forecast error was low and part set-up costs were high. Interpretation of these results is very difficult since the MRP system of the test does not represent any system currently reported in the literature as being used and its hybred characteristics are difficult to evaluate. The authors do however offer several caveats. They indicate that "it is not possible to make a fair comparison between 'MRP' and any alternative support system" since MRP systems vary so widely in their composition and use. "In fact, HPP should not be viewed as an alternative to MRP. We believe that some elements of the hierarchical framework can be constructively used to enhance the MRP system" (p. 234). The MRP II system has, as previously indicated, a full hierarchical structure which has already been compared to the HPP structure. What the authors were really suggesting is a substitution of the highest level in the HPP structure for the production plan in an MRP II framework. How such a new structure would operate was not made clear but the work is important because of its attempt to integrate mathematical models which have not been widely accepted in industry and MRP II which has been widely accepted.

The above work has been followed more recently by another in the same spirit. Axsater (1984) dealt with the integration of HPP and MRP II with a focus on capacity planning. The study suggested that capacity constraints will be more effectively handled if an MRP II system is augmented with HPP. An aggregate production model was used to determine product and machine groups for an aggregate production plan. The disaggregation process was facilitated by changing order release times and by allocating excess capacity to the machines in a machine group similar to the logic employed in shop floor scheduling in an MRP II environment. A simulation showed the cost reductions possible by the combination of the two systems. The integration of the two systems that was proposed by the authors may offer advantages in an industrial setting where, because of the focus on cost minimization, the model may provide a cost efficient planning activity without sacrificing customer delivery.

Although many of the above studies indicated that there has not been widespread acceptance of HPP and aggregate planning models in industrial settings, Gelders and Van Wassenhove (1982) felt that researchers would benefit by reports of such systems, successful or not. The authors reported on two case studies of HPP implementation. In the first case, a rolling mill of 1500 people and annual sales of $300 million, the HPP had been operational since 1979. The second case was a chemical firm employing about 250 people with annual sales of $40 million. The HPP model had been recently implemented in this operation and fine tuning was still ongoing. The two important points made in the study were; 1) the need for the use of slack resources to assist in the formulation and disaggregation process (the general definition of a slack resource is any resource in excess of what is need for ordinary operation of the enterprise) and 2) the need for managerial interaction with the models during disaggregation. Potential infeasibilities are avoided by the introduction of slack in the aggregate planning phase. The slack is in the form of lead time from order to delivery although the authors indicate that other means of introducing slack such as buffer inventories, capacity, etc. would accomplish the same goal. The slack was introduced by human interaction with the HPP at both levels and especially during disaggregation.

In the case of the chemical firm, frequent meetings during the various stages of the HPP process by representatives of a wide cross-section of functions provided the necessary coordination to make the system work. This methodology is quite similar to the methodologies employed in the formulation of the production plan and master schedule in an MRP environment. Production plan formulation also employs active participation from most of the functional areas of the company.

Summary

In summarizing the hierarchical planning work discussed above, several key points should be made.

1. Hierarchical planning is an effective method for the planning of production. It assures that the decision complexity is minimized and that decisions are made by the correct levels of management.

2. Forecasting is necessary to the successful system and forecasting at higher levels of aggregation is likely to be more accurate.

3. Disaggregation is a critically important step in the planning process and efforts to do it properly cannot be minimized.

4. It appears that because of the lack of adoption of HPP in industry and the fact that MRP II does not directly focus on minimizing costs, the vast majority of the industrial firms are operating at costs higher than they should be.

5. The issue of the time horizon which should be covered at each level is largely unsettled except for the advise that it should be sufficient to cover any demand cycle and should also cover the cumulative lead time for production.

6. The production plan of the MRP II system is largely unrecognized in the modeling literature.

7. Capacity and resource issues should be part of every production planning system.

8. Both HPP and the MRP II system are hierarchical in nature and share many similarities.

9. In some circumstances, HPP deals with the rules for aggregating products into families but such is not the case with MRP II.

Empirical Literature

The lack of identification of the production plan in the MRP II model mentioned above is probably not surprising since even those companies which have been identified as successful users of MRP operate the Production Planning activity differently. Berry, Vollmann and Whybark (1979) studied the planning practices of eight companies which had effective Master Production Schedules as determined by a survey of the planning processes of the firms (although the performance of the firm in planning was not directly requested). The production plan varied widely in a number of attributes. For example, resource requirements planning covered a horizon of 10 years (Pfizer, Inc.) to 12 months (Elliot Company) and the period of review of the production plan varied from monthly to quarterly. Although the study was directed to evaluation of the master production schedule, some general principles were concluded about the production plan in the study. These are:

1. The preparation of the production plan is a general management responsibility.

2. The sum of the parts (MPS) must equal the Whole (production plan).

3. The master production scheduler should have the primary responsibility for disaggregating and monitoring the production plan.

4. Good production plans lead to reduced MPS execution problems. These findings relate to the characteristics of the production plan which are only partially agreed to in the literature as we shall see.

Production Plan Characteristics

In reviewing the empirical literature, the focus will be on determining the characteristics of the production plan as understood and used in practice. In addition, the relationship to the master production schedule will be explored. Finally, the review will distinguish between the constituent characteristics of the production plan and the processes related to its regular formulation. It is these characteristics and processes which are the focus of the study as identified earlier. Identification of these characteristics and processes are important to the formulation of the model to be tested.

Perhaps the seminal work in the production plan was by Wight (1974) who identified the production plan as the upper level plan which precedes the master schedule and whose purpose is "to establish a production 'rate' that will raise or lower inventories or backlogs as desired, and usually keep production relatively stable" (Wight, 1974, p. 61). Other ideas expressed in this early work were that the production plan is expressed in aggregate or family of product terms; that it is useful in determining rates for changes in productive activity brought about by plant shutdowns and seasonal sales; that the master schedule uses the production plan as a guide for detail scheduling of "modules" of finished assemblies or product and that resource requirements planning can be done at this level to determine if the master schedule is "in the ballpark" (ibid., p. 61).

After this initial definition, which in many ways did little to differentiate the production plan from a generic view of overall planning, other works including case studies and general principles followed.

One of the most complete works devoted to the production plan is that by Everdell and Ryde (1982). The work not only discusses the principles of production planning, but also provides a case study of production planning in a metal stamping operation.

There are a number of important principles stated in the work. To begin with, the production plan is differentiated from the revenue/shipping plan which counts only that inventory which is actually shipped to customers. In contrast, the production plan is a plan for the overall rate of production some of which will not be shipped but will be part of ending inventory for the planning period. The authors also defined the objective of the production plan. This was "to express, in aggregate terms, a supply plan expressed as a rate projected out into the future--usually at least a year out by months--that will assure the proper level of shipments, consistent with customer service objectives and appropriate levels of finished inventory where they apply, giving consideration to production constraints and costs" (ibid., p. 231). Another principle stated by the authors was that the plan is meant to manage inventories given information on bookings (actual and forecast), backlog (current and anticipated), current inventory and targeted shipping rates.

The authors felt that the plan must be done monthly at least, by the CEO and his staff, and the top materials person should be the secretary of the planning group. They cite the principle that the production plan is the key independent controllable variable and that material and capacity plans must be driven by the production plan and not the shipping plan or the bookings forecast. They suggested a format for a business plan which extends over a six month horizon with all numbers stated in standard cost dollars but they recognized that other units of measure such as pounds or feet are appropriate in different environments. The form is used to display bookings, backlogs, production, shipments and finished inventory. Planned and actual entries of the above categories are used to help create the production plan from the business plan as part of the process. For ease of communication between departments, the authors suggested translating (via computer) between cost dollars, sales dollars and units. This translation activity is looked upon as a means of opening up communications between groups, especially between Sales and Manufacturing.

The production plan is also converted to a resource plan as Wight indicated it might be. The development of capacity related factors is needed to make the conversion possible. Once such factors are developed, then the plan may be converted to resource terms and other plans may be developed such as a manpower plan, a facilities plan, an energy plan and a cash flow statement.

Other general principles espoused are:

1. Management must be totally committed to the planning process.

2. Making small adjustments regularly is better than large adjustments infrequently.

3. The final plan must be focused on one set of numbers used by all and understood by all.

4. Financial data should be used whenever possible.

5. The master schedule should sum to the production plan.

6. The plan may be expressed in multiple units where desirable but it is preferable to use dollars to sum the master schedule to the plan.

7. Historical data should be used to improve the planning process.

8. All data gathering and translation activities should precede the actual production plan meeting.

9. All functional groups should be held accountable for the plan.

The case study presented by the authors, covered a year of production planning by the subject company. Several interesting concepts were introduced. One was the idea of using "available to promise" at the production plan level. This technique was used when the production plan horizon exceeded the backlog horizon. This technique is quite familiar to those who use it in master scheduling. The plan was also "frozen" for one month to minimize production disruption. Additionally, all performances were reviewed monthly (e.g., shipping, MPS, orders and the production plan itself). The company under study showed how effective the plan was during changing business conditions by accomplishing production goals without raising inventories.

Another case study of significance was that of American-Standard, Inc. (Swoyer, 1982). The idea expressed above by Everdell and Ryde that different units help in managerial communication between departments was extended here to the production plan itself as a communication tool. Communication is enhanced both between functional areas and from top to bottom through the organization. In this last regard, the author claimed that "the principal objective of production planning is to communicate executive policy or strategy for operating the business in order to effectively allocate resources to achieve the company's operating objectives..." (ibid., p. 17). This idea of the production plan as a linkage to strategy will be explored in greater detail later. In the American-Standard study, the production plan was seen as a macro level compilation of the master schedule where items are stated in terms of product lines, families or unique groupings. This was contrasted with the "operating plan" which is a statement of the economic and market conditions reconciled with anticipated departmental operating levels and is the key management planning document for this firm. Production planning follows operational planning which is done annually. The procedures associated with the production plan include grouping products into family groups including spares where they are greater than 10% of overall demand.

As noted before, the production plan is stated in aggregate or family of product terms but rarely, if ever, is there advise on how this aggregation should be accomplished. This is unlike the quantitative literature which is often quite specific on the terms of aggregation.

The inputs to the production plan in the American-Standard case are composed of a forecast by sales, current booking position by sales, current inventory position by manufacturing and a target ending inventory by manufacturing. The production plan is then determined from those inputs as follows: Target ending inventory plus the larger of sales forecast or customer bookings minus beginning inventory equals the production plan.

The participants in the planning process are the major operational personnel from marketing, finance, and manufacturing and the top manager. In the production plan meeting, marketing is responsible for discussing sales performance to plan, the outlook or forecast of new orders, the customer backlog position, service levels and any other key indicators deemed appropriate. Manufacturing is responsible for discussion of past performance of the master schedule to previous production plan, the schedule rate for the future, inventory levels and any other key performance measures that are considered important. Finance is responsible for discussion of the past financial performance to plan and the forecast of future performance based on the sales and production forecast. For this company, the production plan (identified also as the business plan) must take place every month "without fail" and to prepare properly for the meeting, most of the major work is done by marketing, manufacturing and finance in prior meetings. Thus the formality and regularity of the meeting is seen to be very important. The study presents a detailed example of the production plan for the company.

The above two studies, taken together, focus on most all of the major issues and characteristics of the production plan in an MRP II model. A summary of these issues which are focused on in the remaining literature review follows.

1. The production plan-master production schedule relationship.

2. The production plan-business plan relationship.

3. The relationship of the production plan to overall firm strategy.

4. The aggregate terms of the plan.

5. The role of forecasting.

6. The financial interface.

7. The control of inventory by the plan.

8. The role of top management in plan formulation and execution.

9. The relationship of resource requirements planning to the production plan.

10. The frequency and formality of plan formulation and review.

11. The participants in formulation and review.

12. The time horizon of the plan.

In each of the subsequent works, the above issues will be addressed. A consensus summary of the empirical view of the above characteristics and relationships will follow.

Following Wight's work in 1974, Mather and Plossl (1978) recognized the importance of the production plan as the prerequisite to the master production schedule. The authors recognized the production plan as a "general statement of operating rates that extends well into the future" (ibid., p. 7). Relating to the 13 characteristics above, the authors believed that the production plan 1) should typically cover two to ten years; 2) is expressed in aggregate output rates such as pounds, dollars, gallons, etc.; 3) is used to determine resource limitations which would prevent meeting the output goals; 4) serves as a summary for management in the near term of what can be accomplished with available resources; 5) is used to set inventory levels; 6) reflects top management's policies with consideration for stabilized labor force and 7) is an agreed to consensus among top level managers on policies and strategies.

Nellemann recognized the variability of Production Plan practice when he stated that "it is an imperfect science requiring certain management judgments..." (Nellemann, 1979, p. 166). Additional key points included the definition and purpose of the Plan: a "process of producing high-level schedules in gross terms...to determine longer-range capacity and material requirements and to assess the financial impact of alternate plans" (ibid., p. 166). Thus, the author proposed the use of the production plan as a simulation tool.

Nellemann also saw the production plan as an aggregate product line plan put together between the various functional members of top management. He felt that it was a top management tool to plan resources, services and inventory investment. Finally he felt it should be the basis by which master scheduling proceeded and that both the master schedule and the production plan performance should be reviewed either monthly or quarterly when the production plan is reviewed/revised.

One of the difficulties of this period which led to a wide variety of perceptions of the production plan was that while the master schedule was well defined by the variety of software which was available on the market, no such software existed for the production plan (Landvater, 1979). Or it may be there was no software because of the wide variety of perceptions of the production plan. Since the concepts of the production plan varied so greatly, it is likely that this was the prohibiting factor in development of software.

The financial side of the production plan was emphasized by Case and by Pendleton both in 1980. Case called for the forecast, production plan and the master production schedule all to be converted into dollar terms for assessment in terms which can provide impact to reviewers. Pendleton cited the connection top to bottom (strategic business plan to production plan to master production schedule) by the financial systems.

Terry Schultz (1981 and 1983) conceived of the MRP II model somewhat differently than has classically been defined. He called the system Business Requirements Planning. He depicts a top level planning scheme of business planning, marketing planning and production planning. Business planning concerns itself with investment planning, earnings, ROI, growth, profits, asset planning, and capital planning ending in the establishment of budgets. This is a departure from the more classical position of the resource requirements plan used to identify both people and equipment needs before capital budgeting can occur. In the Schultz model these capital decisions occur long before the production planning and resource requirements planning activities and these later activities act in a feedback loop to the business planning activities. In any case, the production plan is seen as the logical consequence of shipment planning (backlog, forecast, service) and inventory planning (raw, WIP and finished goods). The capacity planning done from the production plan is called rough cut in the generic sense. In essence, Schultz has conceptualized the sequence of decisions he believes are necessary to a complete production plan prior to releasing information to the master schedule. One significant addition has been made to the production plan meeting discussed earlier. Besides advocating the Chief Operating Officer, marketing, finance, manufacturing and the materials manager, Schultz suggests the presence of the engineering manager to provide product definition. With the exception of the human resource (personnel) function, all the major functional departments are represented at the production planning meeting.

It remained for Mehta to suggest the addition of personnel to the meeting since manpower decisions were being made (Mehta, 1983).

Several interesting points were dealt with in studies by Kneppelt (1981) and Proud (1981). Kneppelt recognized the production plan as the planning step preceeding the master production schedule, resource requirements planning as necessary at the production planning level to insure capacity availability before master scheduling, and forecasting as an input to both the production plan and the MPS, but he also focused on material planning time zones and especially the bills of material consistent with those time zones. He defined a long term time zone associated with the production plan which uses a "Prototype Bill of Materials" (in the case of new products) or a "Super Bill of Family Groups" to plan materials and "Product Load Profiles" to plan resources (ibid., p. 61, 62). In essence these are rough aggregations of materials and resources. The remainder of the paper concerns itself with implementation of MRP II and not the production plan per se.

Both Kinsey and Visagie, presenting at the International APICS Conference in 1981, depicted Production Planning in their own firms; the Bendix Corporation and the Thomas J. Lipton Company of Canada respectively.

There are several points of significance that deserve mention in these case studies. In the case of The Bendix Corporation, the master production plan (as it is called) is validated by capacity considerations and the level of resource planning associated with the master production plan (MPP) is not directly used to analyze long term capacity needs. Secondly, outputs from the master production plan are not only the master schedule but also a capital plan, inventory plan, sales/billing plan, production manning plan and profit projections. Finally, the MPP committee which meets formally and regularly every month, also has the head of engineering as a participant along with the chief operating officer and the heads of marketing, manufacturing, finance and materials. Most of the major work of production planning is done prior to the actual formal month end meeting where previous performance is reviewed and new plans are committed to.

The planning process for the Lipton Company is less formal than that of Bendix. Significant to the process is that the sales forecast, which is the starting point of the production plan, is subject to the analysis of the materials group, who with the sales group, are experienced with the product and its demand. This procedure allows both groups to be comfortable with the forecast. The other key point made in the case study concerned the cost of customer service levels and the trade-offs that could be made with inventory levels. Lipton gathered all relevant data to determine costs and using some rules of thumb based on experience for lost sales due to unavailability of product, formally calculated inventory levels for production plan targets. All this was done during the creation of the production plan and was considered part of the planning activity.

In March of 1982, The American Production and Inventory Control Society held a Master Planning Seminar. Two presenters at that seminar discussed points worthy of mentioning. Pittenger of Cincom

Systems advocated the use of a Family Bill of Materials for use in Production Planning and disaggregation to the MPS (Pittenger, 1982). This family bill is constructed along modular lines with percentages attached to each product that makes up the family. This is one of the few places in the empirical literature where disaggregation is explicitly addressed. On the other hand, Pittenger believed that resource planning can be done from the master schedule and its rough cut capacity planning capability. This is similar to Hyster, Inc. which alters the logic of its CRP system and uses it to generate a five year capacity plan for individual machine groups (ibid., Berry, Vollman and Whybark, p. 133).

Timkin, conversely, uses resource bills to convert the production plan to the resource requirements plan (Muegel, 1982). For Timkin, the production plan is so important that "the approved production rate by product group is to be used in all phases of sales, production and financial planning for the company" (ibid., p. 59).

Common to both studies is the idea that the production plan can be used as a simulation tool to answer "what if" questions much the same as is advocated for the master schedule (see any comprehensive MRP II software package such as AMAPS or Software International).

Returning to the idea of the production plan horizon, several case studies have suggested horizons of one or more years. Iemmolo (1983) in a case study of Joy Manufacturing suggested a Strategic Plan horizon of five years with yearly reviews, a Business Plan with a planning horizon of one to two years with yearly reviews and the production plan of eighteen months with monthly reviews.

Raffish suggests that the strategic level is the business planning level and its horizon is five years while the tactical level is production planning with a horizon of one to three years with monthly reviews (Raffish, 1983).

In both cases the typical hierarchy of business plan to production plan to master production schedule as posed by Wight, is accepted as the standard for an MRP II model.

Resource requirements planning was presented in the empirical literature from a variety of viewpoints. Other than the concept of time horizons, the concept of resource requirements planning has the greatest variability associated with it in the literature. The issues of what resources are planned and what the relationship is to rough cut capacity planning are both subject to disparate points of view.

The two extremes on the point of what resources should be planned in resource requirements planning are represented by Andrew (1984) and Abair and Helle (1984). Abair and Helle, on one hand, believe that only key resources such as machine capacity and tooling availability in key work centers should be considered in resource requirements planning and Andreas on the other believes that facilities, land, capital equipment and long term manpower requirements should be considered at the production plan level. But, in general, resource requirements planning has been seen by most researchers as covering the manpower, equipment, facilities and financial resources of the firm.

There are, of course, other studies dealing with the Production Plan but most reiterate the points made in the literature selected.

Empirical Literature Summarized

A summary of the points made in the literature in reference to the production plan characteristics mentioned earlier follows. In general,

1. The production plan is most often seen as the controlling plan of the master production schedule and the sum of the MPS must equal the production plan. The plan states the rate of production for the firm and is disaggregated to the master schedule.

2. There is a strong relationship between the production plan and firm strategy which will be discussed in greater detail below.

3. The aggregate terms of the production plan are usually families of products and very little direction is given on this aggregating activity.

4. The terms (units) of the plan may vary. Standard cost terms were suggested but any number of other terms (for example assembly hours, machine hours, sales dollars, etc.) are possible with the requirement being that the terms be useful to all in the planning activity or be translated into terms which can be understood by all functions.

5. Forecasting is usually done for families of products represented by the production plan and usually starts the production planning process.

6. The production plan is often stated in financial terms but the plan can also be used to develop cash flow needs for the firm as part of resource planning.

7. One of the primary functions of the production plan is to assist in the control of inventory. The plan takes beginning and targeted ending inventories into account during formulation.

8. The top manager (CEO or COO) are fundamental to the success of the plan. The top manager must insure that planning is done regularly since it is his "handle on the business."

9. Resource requirements planning is the highest level of capacity planning and is done in conjunction with the production plan. As a minimum it is a

verification that the plan is valid with regard to critical resources. In some cases it considers long term resources like facilities and equipment.

10. The production plan must be done formally and regularly. Most often suggested is a monthly review/formulation in a formal meeting.

11. The participants are usually cited as the top manager and the heads of the various functional groups: marketing/sales, production/manufacturing, finance/accounting and materials. Others suggested were the head of the design engineering function and the head of the personnel function.

12. A wide range of time horizons has been suggested but most commonly a rolling horizon of greater than one year was considered the norm. Most commonly, the plan is stated in monthly time increments.

Production Plan - Strategic Plan Interface

To complete the above picture of the production plan as seen by the empirical literature, we turn our attention to the production plan-corporate strategy interface. Many of the MRP II models already discussed, view the highest level of planning in the organization as corporate strategy. Iemmolo, for example, defines the hierarchy of planning as long range strategic planning feeding the tactical mid range of business planning which in turn leads to detail planning by product family at the production plan stage (ibi., p. 26).

Hill identified the production and inventory control function and many of its constituent elements such as scheduling as contributors to the strategic planning activity (Hill, 1982). Hill calls for synergy between corporate strategy and the Production/Operations function. This is not a new idea. Wickham Skinner (1966) recognized the need for manufacturing to play a greater role in corporate strategy.

In the light of these ideas we shall focus on several key points associated with the strategy connection. The first of these is the role of MRP II in corporate strategy and the second is the production plan linkage in the strategy formulation, implementation and control process.

The MRP II system has several attributes critical to the strategy issue. First, it requires strong interaction between functional groups of the company. This was evident particularly in the formulation and periodic review of the production plan discussed above. Second, both planning and implementation (execution of plans) are part of the MRP II system. Third, it is particularly well adapted to the job shop and batch manufacturing environments. This is evident by the infrequency of practitioner articles on use of MRP II in repetitive environments and technically obvious by the job lot paperwork bias of the system.

Fitting the production planning and control system of the company to the strategy of the firm is an important part of the manufacturing-strategy connection. It is cited as the fundamental bias in the design of the production and inventory control system of the company by Van Dierdonk and Miller (1980). Hayes and Wheelwright (1984) also support this idea by indicating that the production planning/materials control area is one of the tactical decision categories of manufacturing strategy. Corporate strategies can be based on a number of attributes or competitive foci. These include cost, quality, flexibility, service, technology and delivery. These have been discussed in whole or in part extensively in the literature (see for example Porter, 1980 or Glueck and Jauch, ibid.). Since the focus of the MRP II system is on-time delivery with low inventory investment as is the focus of most production planning and control systems, and since, as indicated above, MRP II is particularly well suited to the job shop and batch manufacturing environments where product variability is high and order sizes are constantly volatile, MRP II is particularly well suited to the company which wishes to compete on delivery and flexibility. The appropriateness of MRP II may, however change as volumes increase or the company evolves (Pannesi, 1984). For the firm that has identified the delivery and flexibility attributes as critical to their market strategy, the choice of MRP II as the company system is indicated. This is akin to the transformation of conversion from environmental factors to production control systems as defined by Van Dierdonk and Miller (ibid., p. 38).

Another attribute often discussed is the role of information and information processing in the corporate strategy. Information processing capability is cited by Van Dierdonk and Miller as a central issue in the design of a production planning and control systems (ibid., p. 41). Porter and Miller (1985) refer to the "information revolution" currently underway in business today. According to the authors "Information Technology is generating more data as a company performs its activities and is permitting it to collect or capture information that was not available before" (ibid., p. 152). This is almost a description of the MRP II system with its large common data base capability which is a requirement according to Melnyk and Gonzalez (1984). The benefits of a good information system also extend to the implementation of strategy. It is this information system which ties together the activities of all functions of the firm and provides the basis for implementation (ibid.).

St. John (1975) advanced another potential benefit of MRP II that is connected with Strategy. He believed that the production planning and control system of the organization can contribute to the strategic activities in the areas of long range inventory planning and long range capacity planning. As was noted above, the production plan, as part of its fundamental function, considers inventory positions in the long term and the resource requirements plan is used to consider capacity plans over the long term. Accordingly, the MRP II system which provides these planning capabilities can be used in a proactive way to help in strategy formulation.

MRP II also provides a top down view of manufacturing and its capabilities (Andrew, 1979). This view is necessary for the top manager to properly coordinate strategic plans and their implementation (ibid., p. 238). This view is additionally necessary to identify current capabilities which may be the bases for strategy.

This is consistent with the views of Charkravarthy (1979) who believed that although strategy formulation is an iterative process, the starting point for its formulation is the current capabilities of the firm. Further support for this position may be found in Hayes and Wheelwright "It (manufacturing) must communicate clearly to top management the constraints it operates under, the capabilities it can exploit and the options available to it. And it must seek collaborative relationships with other functions." (ibid., p. 41).

Again, it should be clear that MRP II embodies the traits called for by these authors. With its long, medium and short range planning capabilities, managers using MRP II can not only present manufacturing's capabilities to top management through the production plan and resource requirements plan, but through the use of MRP II, management can execute new strategies (consistent with the system's focus on flexibility and delivery) in a flexible and expeditious manner. Further, the successful MRP II system fosters (perhaps even forces) collaborative relationships between functional departments. This is nowhere more obvious than in the preparation of the production plan.

Finally, MRP II provides two additional capabilities to the strategic management activity. MRP II is designed for management to react logically and expeditiously to the changes in the environment which come with such frequency today and MRP II can be used as a tool to develop slack to absorb environmental changes. This is consistent with the needs expressed by Meyer (1982), Bourgeouis (1984) and Hofer (1974). The idea of investing in slack is also supported by Van Dierdonk and Miller who claim "By investing in slack resources, such as excess capacity, inventories, or backlogs, and organization can make the production planning and control task either less complex, less uncertain, or both" (ibid., p. 40). This would then tend to enable the organization to absorb the uncertainties of the environment. Also, the simulation or "what if" capability of the MRP II system described by Melnyk and Gonzalez (ibid., p. 128) can be used not only to test alternate strategies during formulation and analysis but it can also be used to determine the merits of alternative reactions to changes in the environment.

Turning to the role of MRP II and specifically the production plan in strategy implementation, one firm insures that the strategies of the firm are coming together properly by having the top managers who participate in strategy formulation also sit on the production planning committee. This forms the important link between strategy and the production plan which can be seen as a critical implementation tool (Pannesi and Melnyk, 1984). This arrangement between strategy and implementation is described by Bourgeois and Brodwin as "The Collaborative Model" of implementation and is cited as being particularly useful in environments which are "more complex and, perhaps, less stable where the chief executive or division manager is unable to perceive, assimilate and comprehend the totality of his organization's activities" (Bourgeois and Brodwin, 1984, p. 249).

As we have discussed above, the MRP II environment may have these very characteristics since it is designed to operate best in a job shop or batch manufacturing environment which is usually very complex.

Various views have been advanced on the nature of the implementation task. Two views which directly relate to the subject at hand are those of Schendel and Hofer (ibid.) and Roush and Ball (1980). Schendel and Hofer claim that "...formulation and implementation tasks...must be integrated if organizational purpose is to be achieved." And "sometimes (implementation and formulation tasks are done) formally through a single, integrated formal planning system that includes the strategic planning system and the operating planning system (e.g., budgeting, scheduling and control systems." And "formal planning systems...in many instances...are used more for implementation than for formulation" (ibid., p. 219). If one conceives of the MRP II system as linked to the strategy system of the firm, then the basis for implementation is in place. Further, Schendel and Hofer believe that the implementation concerns itself with structure, processes (systems), and behavior (people) (ibid., p. 222). Roush and Ball also feel that strategy implementation requires attention to structure, people, culture and control systems (ibid., p. 4).

In general, the MRP II system and the production plan do not directly prescribe any structure for the firm other than that implied by the general trend for the implementing unit to be localized to a plant or facility rather than a multi-plant operation. The MRP II system is so largely company wide that it satisfies the condition of a "system" for implementation. People are, of course, central to the success of any system. In the case of MRP II considerable effort is usually expended in assuring that all are supportive of the effort. It has been shown over and over that when this does not happen, the system is usually unsuccessful (see Melnyk and Gonzalez for some discussion of these issues).

It is not the intent of this review to focus on the people issues of MRP II since that is a separate and complex task in itself. Suffice to say that the Production Plan by the nature of its cross-functional planning and the agreements arrived at during the process, assures close and supportive interaction between managers.

Returning to the Roush and Ball model, the authors focus on the development of a strategic control system to insure implementation success. They cite several conditions to achieve success. These include assuring performance criteria are established in advance of implementation, that measurement methods exist to measure progress against those criteria, that a reporting system be in place to accumulate measurement information and that corrective action be specified. The production plan establishes specific performance criteria such as production rate and inventory levels that, if tied to the strategic plan, will be consistent with it. The plan also specifies the information to be measured including that which it sums from the master schedule, and the reporting system offers information on results during each planning session. Corrective action cannot be specified in advance since these actions depend on the character of the problem. Roush and Ball decry the problems of the CEO in managing the implementation process saying "In almost any large organization the network of administrative and control systems is so extensive and complex and involves so much delegation, that the essential simplicity of many important issues facing the CEO can easily be lost" (ibid., p. 8). In the case of MPR II and with the use of the production plan as a linking mechanism to strategy, much of that administrative complexity is simplified and elevated into clear cut issues which are easier to comprehend.

In summary, then, the MRP II system and the production plan are particularly well suited to the implementation task of strategic management because many of the characteristics demanded during implementation are present in this powerful tool.

Chapter Summary

The above literature review dealt with the production plan from three aspects: modeling findings, empirical findings and from the strategy point of view. The production plan in an MRP II environment has, according to the above literature, the following characteristics.

1. It is aggregated at the family level.

2. It is used to set the rate of production for the firm.

3. It is used to control inventories and backlogs.

4. It is formulated/reviewed regularly and formally.

5. It is formulated/reviewed on a monthly or quarterly basis in most cases.

6. It is formulated/reviewed by the COO and his staff.

7. It requires formal and regular forecasting as an input.

8. It is the main input to the master schedule and authorizes the level of master scheduling.

9. It is done each time in conjunction with resource requirements planning.

10. It is often stated in a number of different terms which are translated to be meaningful for each functional group.

11. Its performance is regularly measured.

12. It is a means of implementing corporate strategy.

13. It covers a time horizon at least as long as the cumulative (total) lead time of the product manufactured and as far out as the lead time to acquire the resources in support of the plan.

These characteristics and the general promise that those companies with a production plan perform better than those without are the central focus of the study. Specific hypotheses are given in subsequent chapters.

CHAPTER 3

RESEARCH QUESTIONS AND MODEL

The research questions addressed in this study, as already stated, are concerned with 1) the effect of the production plan on MRP system success and 2) the importance of each of the various characteristics of the production plan to the overall operation of the plan.

But what is a "successful" MRP II system? Any production planning system (and certainly MRP II focuses on production planning as a key element of the system) has, among its general goals the production of product to meet customer needs on a timely basis without incurring any unnecessary expense, thus allowing the firm the opportunity to earn a profit. In general this goal can be translated into three often heard goals: meet schedules; deliver on-time; and do these with a minimum of inventory. A successful system can then be defined as one in which schedules are consistently and regularly met, product is consistently and regularly delivered to the customer on time, and these criteria are accomplished while meeting inventory goals that management is satisfied with. In an MRP system, the schedule most often referred to in this regard, is the master production schedule.

The question then becomes, in absolute terms, what level of performance of these characteristics is defined as "successful" and what is not? For example, if a firm regularly completes 95 percent of the jobs as scheduled in the master production schedule, can this be defined as "success"? How about 99 percent or 90 percent? To further complicate matters, the other performance measures of "success" must also be considered and we need to also address the question of whether each measure should be weighted equally. The new question becomes what level of performance of all three of the above measures can be considered to define the term. This issue is obviously open to considerable debate and cannot easily be resolved. Since the answers are likely to be firm specific, the study did not address these issues in an absolute sense but instead chose to rank firms on the above criteria on a relative basis. Thus, for purposes of the study, a firm which regularly meets its MPS at a 95 percent rate can be considered more successful than one which performs at a 90 percent rate regularly, all other things being equal. This comparative approach has been chosen for all the "success" measures noted above. Given the above understanding, the model which forms the basis for the study may now be introduced.

The Model

As we have indicated earlier, the hypotheses deal with the two areas identified above. These will be detailed further and stated formally in the following discussion.

Dependent Variables

The three measures discussed above are used in the model to define MRP system success. In an MRP system, it has been shown by Anderson et al. (1978) that those three measures are related to a fourth measure, the MRP system class defined by Oliver Wight (1977). In general, a company with a Class A system usually outperforms a company with a Class B system in those three attributes. This measure must be used with caution since, in the survey instrument (to be discussed in detail in Chapter 4), Class of system is self appraised by respondents and a great variety of assessments may be expected for performances which are approximately equal.

The dependent variables of the model are then:

* Master schedule performance
* On-time shipping performance
* Inventory performance
* Class of MRP system

Master Schedule performance may be defined as the average percent completion of scheduled jobs called for in the weekly Master Production Schedule.

On-time shipping performance is a little more difficult to define since, measurement depends on the circumstances of the customer promise. It is possible, for example, to have more than one promise made to a customer. Further, separate promises may be made by sales and manufacturing. The researcher's experience indicates that in some organizations sales and manufacturing each make their own promises and each measures on-time delivery based on their own promise. Since the questionnaire will in all likelihood be answered by a manufacturing or materials person, the answer may be biased. However, in the "more successful" companies it has been observed by Wight (1974) that the sales promise and the manufacturing promise are quite often the same. In such a case, the percent on time delivery can be used with less concern.

Inventory performance is defined as the degree to which inventory goals are achieved, measured in percent. Of course, there are numerous difficulties with such a measure. This measure presumes that the goals set by management are reasonable and achievable. Thus, evaluation of reasonableness is subjective and firm specific and therefore difficult to ascertain. The frequency of such inventory goal setting may also be a problem and could relate to the achievability of the goals. Further discussion on this point can be found in Chapter 4.

Finally, the definition of the class of the MRP system can be found in the questionnaire in Appendix A. It is adapted from the Anderson et al. study (1978).

Independent Variables

Independent variables are those associated with the Production Plan.

For the study, the following variables, all of which are derived from the literature as stated earlier, are considered to represent the Plan:

* Period of formulation/review of the Plan
* Plan horizon
* Plan participants
* Formality of the Plan
* Regularity of the Plan
* Plan Procedures
* Plan use
* Plan performance

* Resource Requirements Planning

* Forecasting formality and regularity

Period of formulation/review of the production plan has always been cited in the literature as either monthly or quarterly with the preponderance of the literature citing a monthly planning period (see for example, Berry, Vollmann and Whybark, 1979).

The definition of the Production Plan indicates that the horizon should be sufficient to plan the labor, "equipment, facilities, material and finances required to accomplish (it)" (APICS Dictionary, 1984, p. 24).

The Plan horizon has been previously stated as extremely variable according to the literature and since it would be extremely difficult to determine how long it would take to acquire facilities and equipment, the model only attempts to determine what the horizon is and will explore the relationship between horizon and success.

Plan participants according to Berry, Vollmann and Whybark (1979) are expected to be at least the Chief Executive Officer or Chief Operating Officer and the major executives of sales, manufacturing and materials. The model proposed for this study also supposes that executives from the engineering and financial groups will also be involved directly in the production plan formulation and/or review.

The plan is expected to be formulated and reviewed on a formal basis with procedures established for this activity. The degree of formality, (including such activities as a formal, month end meeting) is expected to affect system success also.

The model of this study assumes that the more effective plans are those which are formulated with great regularity; i.e., every month or every quarter.

The master scheduler should receive the plan each time it is completed to be used as the basis for the next month's (or next quarter's) schedules. In addition, other groups may receive copies of the plan to assure functional performance to it for the next planning period.

Resource requirements planning is part of the model of the plan and is expected to be used as a check on the validity and achievability of the plan each time it is formulated or reviewed. The literature identifies a wide variety of potential RRP techniques and this attribute is necessary for the first cut at capacity considerations in an MRP system.

Finally, the model indicates the presence of forecasting as a critical element in the production planning activity. This is supported throughout the literature discussed above.

Measurement problems with these characteristics and the measurement approach will be discussed in detail in Chapter 4. Each of the above characteristics of the production plan make up the plan construct and are expected to affect the overall performance of the MRP system. They are represented as measures of the production plan construct in the Figure 3-1. The following discussion covers those expected relationships.

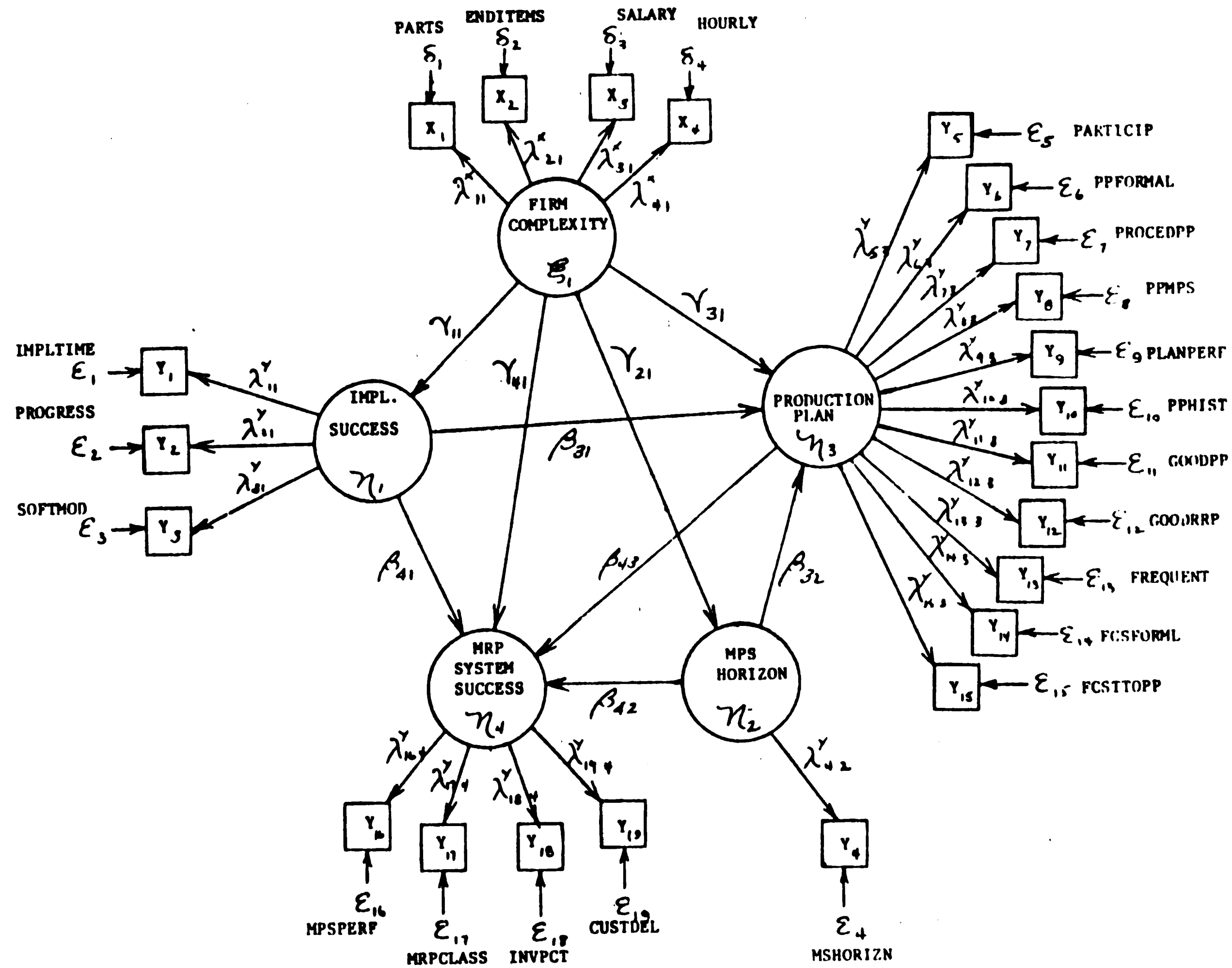

FIGURE 3-1

FIVE VARIABLE MODEL

Period of Review

For example, production plans whose period of review exceeds quarterly are not likely to be as useful to the master schedule as those which are done on a more frequent basis. This is because, changing conditions in the marketplace must be accommodated in production planning on a timely basis to assure that the firm is responsive to the needs of their customers.

There is a strong relationship expected between the lead time of the product, the current backlog and the period of review of all production plans. A company with a long cumulative manufacturing lead time and a large backlog which extends beyond the cumulative lead time has in effect, assured little changes in their environment. Accordingly, the period of review of the Production Plan (and for that matter the master production schedule) can be extended considerably without sacrificing performance. In general then, the period of review depends on the stability of the manufacturing and market environment. For most manufacturing companies, the period of review is expected to be one month as indicated in the literature (e.g., Berry, Vollmann and Whybark, 1979). This period of review should enable the firm to monitor the master schedule on a regular basis and incorporate changes due to fluctuations in the environment into the firm's plans especially those dealing with resource management and product mix.

Production Plan Horizon

The horizon of the plan as indicated above, must be sufficiently long to carry out changes necessary to resource management. This affects success in the obvious ways. Production plans of insufficient horizon will not allow the master schedule to accommodate changes which require resource reallocations especially when those reallocations have a lead time in excess of the production plan and the master production schedule. This will adversely affect master schedule performance. This then can directly affect customer delivery since poor execution of the MPS is likely to cause missed deliveries as well as excessive inventories when the wrong things are made. All of these subordinate problems are associated with poor master schedule performance.

The participants in the plan formulation and review are also critical to the success of the MRP system. Since the plan decides the operating level of the company, the Chief Executive Officer or Chief Operating Officer of the firm, plant or division (any of these may be possible since the implementing unit of MRP may be any of the above) exercises policy through participation in the planning process. In the absence of the CEO/COO, either his wishes must be communicated to the planning group, or independent decisions may be made concerning operating levels and resource management which are inconsistent with the overall goals of the firm. While this may not directly affect success as we have defined it, certainly the firm may not be pursuing the overall goals of top management.

Two groups which clearly must participate are marketing and manufacturing. The essence of the plan is to provide a sensible response to the needs of the marketplace within the capabilities of the firm to respond. Manufacturing needs the inputs of sales in the form of a forecast to provide direction not only in volume, but also with regard to mix. Sales, must understand the limitations of the manufacturing activity and also must understand the strengths of the manufacturing unit which can often be used as a competitive weapon (see for example Hayes and Wheelwright, 1984). Without the participation of both these groups, it is unlikely that a realistic or responsive MPS will be generated and performance will suffer.

The participation of the financial group is also important since this group must assure that the Plan can be executed with regard to financial resources. Failure to do so would cause the potential failure of the MPS to perform properly since, in executing the plan, significant financial resources are usually required. Suppliers who have not been paid, excessive debt, etc. which are potential results of poor financial planning will prevent success in executing the MPS. Further, the role of finance in determining that the plan meets the revenue goals of the firm provides a check on the agreements of sales and manufacturing and also speaks to cash flow and upper level plan (strategic and business) execution.

The contributions of the R&D/Engineering group are also important since this group provides critical information such as planned support to current products and the timing of availability of new products. New products may be a substantial part of the mix scheduled at the production plan level. Support of existing products both in terms of new options and features and in terms of solving current technical problems is important to assure success of the MPS. The implications to customer delivery and inventory are obvious.

Production Plan Formality and Procedures

Formality and the procedures associated with that formality of plan formulation or review, are critical to success since both of these legitimize the importance of the plan and assure clear communication to the master scheduler as to what is expected from the MPS in the coming period.

As indicated above, the plan must be formulated regularly since extended periods of time without planning can result in the need to make massive changes in the plan and the master schedule which it drives. This in turn causes severe disruption to the manufacturing activity and often results in needing tasks performed which are impossible to achieve in the time constraints provided.

Master Schedule Linkage

One of the most critical attributes of the production plan is the linkage with the MPS. An MPS without the guidance of the plan can easily result in improper product mix, poor response to customer needs and resource demands that cannot be provided. This would assure poor performance in all the dependent variables identified above. The plan can also be used to provide the direction for resource acquisition or disposal. In this case, the plan can be the basis for creating equipment and labor acquisition plans to support the master schedule. This "usage" attribute is therefore critical to success of the MRP system.

Resource Requirements Planning and Forecasting

The resource requirements plan has been discussed extensively in conjunction with other attributes of the plan above. It should be clear how this attribute affects success.

Forecasting is another important attribute for success since it is used to initiate the plan and since it provides the best information available from sales as to the needs of the marketplace. Forecasting is a fundamental part of all manufacturing planning. The formality and regularity of the forecasting effort should be especially critical to success since infrequent forecasts may not allow a reasonable time for manufacturing planning to respond to change.

Confounding Variables

Three variables have been identified in the literature above as confounding to the study in that they affect both the independent and dependent variables and their effects must either be controlled for or they must be sorted out during the statistical analysis. These are:

* Implementation time and progress of implementation which defines implementation success.
* Product lead times compared to MPS horizon.
* Firm complexity.

Their constructs and relationships are now explored in conjunction with the two principal constructs of the study (production plan and MRP system success).

Implementation Success

Anderson et al. have shown that the success of MRP implementation increases with the length of time of implementation (1978). This means that the success of the MPS and the other dependent variables may simply be due to the fact that the master schedule has been improved consistently over time and focus on the other variables has also improved their performance. Correspondingly, it may be that the longer the company has been at implementation, the more likely that they have developed a production plan and its attributes. Thus it is difficult to untangle cause and effect relationships in this case. Further, temporal relationships may also confuse the situation. It is possible to have a production plan withut having a master schedule and vice versa. While it is advantageous from a statistical causality viewpoint to believe that the MPS precedes the production plan since most software and most implementations focus on establishing the master schedule early as one of the modules of the MRP system software and since there are few systems which have a separate production plan software module, in fact, the opposite may be true.

Master Schedule Horizon Considerations

The second confounding variable is more a set of conditions which confound the relationships. As mentioned earlier, a company with products which have a very long lead time and which have a backlog of orders or an inventory level which covers well beyond the lead time of the system may well control production through the operation of the master production schedule alone. (Rough cut capacity planning commonly done in conjunction with the MPS would also be necessary.) In such a case, the existence of a production plan may contribute little to the effectiveness of the master schedule and the rest of the system.

Firm Complexity

Finally, the firm complexity construct as defined by the number of parts, assemblies, MPS items and people can easily confound the relationships. The more complex the implementing unit, the more difficult is MRP implementation since communication is a central part of the MRP implementation process and it has been shown that increases in numbers of people increases communication difficulty (Galbraith, 1973). Further, as the complexity of the firm increases, the MPS horizon and the forecasting horizon is lengthened (Hayes and Wheelwright, 1984). Also, as product complexity increases, manufacturing operations also become more complex causing planning difficulties (Hayes and Wheelwright, 1984). This directly confounds the relationships in the study. A discussion of the statistical means of control for these problems will be found in Chapter 4.

The Hypotheses

The above discussion leads to the statement of the hypotheses to be tested in the study. These are:

H1: A company with a production plan has a higher level of system performance than a company without a production plan.

The remaining hypotheses relate to the characteristics of the production plan.

H2: The period of formulation/review of the production plan is important to the success of the MRP system. To be most effective, the plan should be formulated or reviewed monthly or at worst, quarterly.

H3: The participants in the formulation or review of the production plan should be representatives of the major functional areas of the company. These include: marketing/sales, operations/production, finance/accounting, engineering/R&D, materials and the chief operating officer. The more of these functions that are represented, the greater the success of the production plan and the MRP system.

H4: More formal production plans lead to more successful production plans and more successful MRP systems.

H5: Production plans which have more strict procedures and which are regularly followed are more successful and lead to more successful MRP systems.

H6: Production plans which are used in the preparation of the master schedule are more strongly associated with successful MRP systems.

H7: Production plans which have resource requirements planning done each time production planning is done are more successful and lead to more successful MRP systems.

H8: Production plans which have formal and regular forecasting done with them are more successful and lead to more successful MRP systems.

H9: Better production plan performance leads to better MRP system performance.

In summary, the research proposes to study the relationship between the production plan and the successful MRP system. The hypotheses fall into two issues; the influence of the production plan on the success of the MRP system and the importance of the constituent elements of the production plan. The model proposes a direct relationship between the production plan and the success of the MRP system. The model also identifies confounding variables which could interfere with the study of the central relationship unless controlled.

We now turn our attention to the research design, measurement methods and proposed statistical analysis.

CHAPTER 4

RESEARCH METHODOLOGY

As discussed above, survey research represents a logical progression from the numerous case studies on the production plan which dominate the empirical literature. Accordingly, a survey of MRP companies was undertaken.

Survey Research

The subject of survey research has been covered extensively in the literature since the pioneering work of Samual A. Stouffer and Paul F. Lazarsfeld. Modern representative works include those by Simon (1969, 1978), Babbie (1973) and by Schaeffer, Mendenhall and Ott (1979). Survey research offers many distinct advantages to the researcher. The most important of these is the opportunity to reach a great many more subjects for analysis than is possible with a case study approach. In addition, it is possible to capture some idiosyncratic behavior that might not otherwise be possible using case studies alone. Further, a wide range of responses helps to define the full extent of behavior under consideration by the researcher. The formulation of broader, more general principles and tests of hypotheses over a larger sample of the population under consideration is possible and thus the research often gains strength in analysis. Other benefits include the fact that there is no interviewer bias, the respondent can answer at his/her own leisure and the cost per questionnaire is relatively low compared to other research types. The time invested by the researcher is least if the survey is conducted by mail rather than by telephone interview or by personal interview which are alternate means of conducting survey research.

Of the three types of survey research; description, explanation and exploration, this study was primarily considered to be explanatory, however, there are both descriptive and exploration elements connected with the study as will be seen below.

The unit of analysis was chosen to be the MRP implementing unit. This could be a company, plant or division which is implementing or has implemented an MRP system. The survey was a cross-sectional one. Even though the time frame of response occurred over a three month period it is unlikely that longitudinal influences can be found.

The population that the sample was drawn from is the population of all MRP system users in the U.S. Identification of the population elements came from three primary sources. These are: MRP consultant/educators class lists, American Production and Inventory Control Society membership lists and MRP software suppliers customer lists. MRP consultants/educators were chosen because they are most likely to have as students those practitioners who are in the process of or are contemplating implementation of MRP systems. APICS membership lists were chosen because APICS members are often involved in MRP systems since APICS has been a strong supporter of the MRP movement since the early seventies. The customers of MRP software system suppliers were chosen since they are presumed to have purchased MRP software in conjunction with future implementations.

There was some concern that a portion of the population represented by those firms who developed MRP software in house over a significant period of time may not be found in any of the sources stated above. Unfortunately, there was no good way to identify and directly sample this group. Further, it may be that some firms in this group do not recognize production planning and control systems developed in house as being an "MRP" system. Such is the case with an auto manufacturer who developed in house software which followed the essential MRP logic but did not make the connection between its software and the MRP system and did not recognize its system as an MRP system.

Chapter 5 discusses the character of the sample respondents and identifies those with in house developed software. In all, nearly eight thousand names were compiled from these lists. To ensure that there would be little bias due to geographical considerations, the names were selected from all over the U.S. There was no overt control over industries selected but as the results in Chapter 5 will show, a wide variety of industry types was represented by the sample. The eight thousand represents a good number of the total population since a recent list of MRP software suppliers indicated that the total number of licenses for, or outright purchases of MRP software packages must be in excess of 17,500 which is the number sold by the top sixteen companies alone (Grey, 1986).

"The ultimate purpose of survey sampling is to select a set of elements from a population in such a way that descriptions of those elements (statistics) accurately describe the total population from which they are selected" (Babbie, p. 83). Since random selection is the key to this process, assuming that the compiled list is representative of the population, 2500 company names were selected randomly using a random number selection process. This random process is, of course, absolutely fundamental to the statistical inferences and procedures used in the study. The 2500 companies selected were sent a questionnaire with a cover letter (see Appendix A).

Questionnaire Design

There are a number of issues connected with the design of a questionnaire. First it is important to target the questionnaire for a particular respondent who is competent to answer (Babbie, p. 142). In this case the resondent of choice was the manager of materials or the manager of a similar production and inventory control function since it was felt that a person in this function was more likely to have the information required in the questionnaire on planning systems in an MRP environment.

Second, even though shorter questionnaires tend to receive higher response rates than longer ones, all else being equal (Simon, p. 197), the questionnaire turned out to be seven pages long with forty-five questions. The length of the questionnaire probably resulted in the relatively low return rate noted later in Chapter 5.

Length of the questionnaire also may affect the accuracy of the responses since longer questionnaires lead to boredom and less accurate answers (Schaeffer et al., p. 28). This may also have affected the return rate as discussed in Chapter 5.

Next, levels of measurement were considered. In general, an effort was made to construct questions such that responses could be measured on a ratio scale. This was not always possible and responses involving interval, ordinal and even nominal scales appeared in the questionnaire. In the case of nominal scale responses, an attempt was made to use these responses only as classifying variables to separate responses into categories for analysis. This is the case with the have/do not have production plan question which was used to group the return into two sets for the discriminant analysis and to identify the companies with production plans for the major analysis. Many of the interval scales were constructed along the lines of the "Likert scale" which deals with strength or degree of an issue.

Open ended questions were very limited and the problems of classifying responses was thus minimized. On the other hand, close ended questions depend on the researchers ability to structure questions that the respondent can easily identify with and understand. Each question was designed to be exhaustive and answers mutually exclusive.

All major terms were carefully defined for the respondent so that very little was left to interpretation. Every attempt was also made to construct the questions in a non-biased manner avoiding terms or phrases which could influence the respondent to reply in a certain manner. Extensive testing eliminated those questions with such problems.

Questionnaire Categories

The questionnaire was divided into five major categories. Part A dealt with company variables such as size, sales, types of products and volumes. Part B asked for a basic description and current status of the firm's MRP system. Part C covered the dependent variables, system performance. Part D represented the main part of the study, the production plan and its constituent elements. Part E gathered information for future study and dealt with basics of strategic planning done by the firm.

Respondent Issues

Once the sample was drawn, the questionnaire was mailed along with a cover letter and a postage paid return envelope to encourage returns. The respondent was given an opportunity to receive a copy of the results if he provided his name and address on the questionnaire. Nearly all did.

The issue of nonresponse bias was of initial concern. If some relevant part of the population as represented by the sample did not return the questionnaire, the results might be biased (Simon, p. 316). One method of determining if sample nonrespondent bias may be present is to see if the respondents represent a good cross section of all areas of the sample. This issue will be analyzed in more detail in Chapter 5 but in general, it appears that there was a good cross section of respondents. Other nonresponse biases were difficult to determine and avoid. Nonrespondents were assumed to come randomly from the sample since there is no identifiable reason to assume differently.

Respondent Variability

Beyond the question of bias which is the systematic tendency to deviate from the "true" value (Simon, p. 273), there is the question of measurement error due to respondent variability. This variability can traditionally occur as expectancy effects, lack of knowledge, fallibility of memory, cover up and rationalization and repression. Of these, the most likely to be damaging to this survey is the errors generated by the lack of knowledge or fallibility of memory.

In the case of lack of knowledge, a respondent who does not know specific information, especially that information concerned with system performance, can be a great source of measurement error. By requesting that the materials manager or his equivalent complete the questionnaire, error from this source should be reduced. Since measures of MRP system performance (the dependent variable) are imperative to the study, respondent estimation of these performance numbers was allowed when exact performance information was not known. Respondents replied using estimates far more than was hoped. This will be discussed in greater detail in Chapter 5.

The problem of fallibility of memory is closely associated with the above problem. For some issues, the same question was asked in different forms in different parts of the questionnaire to identify those respondents which potentially had this problem. Inconsistency of response may be an indication of these problems. One of these checks was done in the case of use of the production plan and the results are discussed in Chapter 5.

The problem of cover up (or the "publicity effect") was felt to be less likely. The questionnaire specifically stated that results would not be identified with specific respondents but only reported in aggregate without identifying company names. In general, with very few exceptions, the responses were frank and open,often including short notes to apologize for the poor performance of the firm or invitations to call and get more detailed information.

While in cover up the error is assumed to be generated because of a conscious distortion or withholding of the truth. In the case of rationalization and repression the issue is one of subconscious distortion. The possibility of a respondent subconsciously distorting the truth is possible although difficult to imagine. The promise of anonymity may minimize this problem.

Connected with both of the last two issues is the problem of deception. A respondent may deliberately try to deceive the researcher but the question of motive must be raised. There seems to be little motive for the respondent to deceive the researcher other than to make his firm "look good." Since results will be published in aggregate and identification of specific firms withheld, credit for firm performance characteristics cannot be directly taken and there appears to be little reason beyond that to deceive the researcher. Of course, it is always possible that the respondent does not believe that the responses will be held in confidence but this would seem to be more of a reason to not reply than to deceive.

Of all the above problems, as already stated, the two of greatest concern are lack of knowledge and fallibility of memory. One means of reducing this problem is to follow up each questionnaire with a subsequent visit or call to try to verify critical information. Such an effort would be extremely costly and time consuming and must be rejected.

Questionnaire Testing

During preparation, the questionnaire went through numerous changes. In all, there were seventeen revisions before printing.

The first actual pretesting was done with a small group of local materials personnel who completed the questionnaire and then communicated their problems, confusion, suggestions, etc. The questionnaire was revised and retested with three more materials managers. The questionnaire was again revised based on comments received from these people. A final test was performed on a master scheduling class given by an MRP consultant/educator. The class was made up of materials professionals. Revisions to the questionnaire were finalized at that point and the questionnaire was printed and mailed.

Data Analysis

Analysis proceeded in four separate and distinct steps. The first step was an overall analysis of the results done by examining the frequencies of the response for each question to examine the potential for bias among other things. Next, those issues which were of particular interest were identified and a simple Pearson correlation was performed again to examine the issue of bias. Next, a discriminant analysis was performed discriminating on whether a company has a production plan or not and using success variables as discriminators. This was done to examine the hypothesis of the effect of the production plan on MRP system success. Finally, all those companies which had production plans were identified and the LISREL analysis was performed to test the hypotheses and control for confounding variables.

Frequency Data Analysis

At the first step, frequency of response to each question was looked at for the entire response population and then for those with production plans. Special consideration was given to those circumstances where the distribution or standard statistics provided by SPSSX such as mean, standard deviation, median and standard error, varied significantly between the two samples. In this way bias of the sample was examined. An example of the information obtained in this preliminary analysis concerned the number of different industries responding to the questionnaire who had plans compared to those who did not. Whereas in the total sample, 96 industries were represented, in the sample of those companies which had a production plan only 79 industries were represented. Thus, the question of bias based on industry type arises. This will be discussed in Chapter 5.

Discriminant Analysis

A discriminant analysis was performed to assist in the evaluation of the hypothesis that having a production plan is more strongly associated with MRP system success than not having one. The classification variables chosen were the MRP system success variables; master schedule performance, customer delivery performance, inventory performance and MRP class.

In the case of discriminant analysis, the predictor variables should have a multivariate normal distribution but the analysis is fairly robust under conditions of non-normality. The intent of the discriminant analysis was to see if companies can be categorized into groups with and without production plans by using the success variables alone.

The test proceeded by first calculating the group means and group standard deviations for the four discriminating variables. Next, the pooled within groups correlation matrix was calculated to examine the interdependencies among the predictor variables. Then the Wilkes Lambda statistic was calculated. This is the within groups sum of squares divided by the total sum of squares. The F test thus derived can be used as an ANOVA for the group means. Finally, the discriminant function which is a linear combination of the independent variables was formed and used for the assignment of cases to groups. The discriminant score is then calculated for each case and each case is assigned a group (with production plan or without production plan). Each is then compared to the actual data which shows whether that particular case (company) had a production plan or not. Predicted vs. actual data is summed and compared to a probability of .5 (the probability that the case could be assigned to either group randomly). These measures are also plotted and compared. Details of this test may be found in Chapter 5 along with the results of the discriminant analysis.

Lisrel Analysis

Finally, the data was analyzed by the LISREL VI program of Joreskog and Sorbom (1985). All those cases which had a production plan were taken as the subgroup for analysis. Since it cannot be assured as mentioned earlier, that residuals of the path analytic equations are not correlated, that causality is unidirectional or that variables will be measured without error, the techniques of path analysis are not applicable (Pedhazur, 1982). Instead, the technique of structural equation models best suited to the above conditions is LISREL developed by Karl G. Joreskog of Sweden (1974). Lisrel consists of two major subdivisions: the structural equation model and the measurement model as indicated earlier. The structural equation model refers to relations among exogenous and endogenous variables. In LISREL, latent dependent or endogenous variables are designated as η (eta) and latent independent or exogenous variables are called ξ (ksi). The structural equation model is:

$$\beta\eta = \gamma\xi + \zeta$$

where η (eta is an m by 1 vector of latent endogenous variables

ξ (ksi) is a n by 1 vector of latent exogenous variables

β (beta) is an m by m matrix of coefficients of the effects of endogenous on endogenous variables

γ (gamma) is an m by n matrix of coefficients of the effects of exogenous variables on endogenous variables and

ζ (zeta) is an m by 1 vector of residuals

The measurement model describes the relationship between unobserved (latent) and observed (measured) variables. The equations that describe this model are as follows:

$$y = \lambda_y\eta + \varepsilon$$

and

$$x = \lambda_x\xi + \delta$$

where:

y is a p by 1 vector of measures of dependent variables

λ_y (lambda) is a p by m matrix of coefficients or loadings of y on the unobserved dependent endogenous variables

ε (epsilon) is a p by 1 vector of errors of measurement of y

x is a q by 1 vector of measures of independent variables

λ_x (lambda) is a q by n matrix of coefficients or loadings of x on the unobserved independent exogenous variables and

δ (delta) is a q by 1 vector of errors of measurement of x.

Referring now to figure 4-1, the model under consideration, reproduced here for convenience, the structural equations and measurement equations are stated below.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -\beta_{31} & -\beta_{32} & 1 & 0 \\ -\beta_{41} & -\beta_{42} & -\beta_{43} & 1 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{bmatrix} = \begin{bmatrix} \gamma_{11} \\ \gamma_{21} \\ \gamma_{31} \\ \gamma_{41} \end{bmatrix} \xi_1 + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \zeta_4 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \\ y_{10} \\ y_{11} \\ y_{12} \\ y_{13} \\ y_{14} \\ y_{15} \\ y_{16} \\ y_{17} \\ y_{18} \\ y_{19} \end{bmatrix} = \begin{bmatrix} \lambda_{11} & 0 & 0 & 0 \\ \lambda_{21} & 0 & 0 & 0 \\ \lambda_{31} & 0 & 0 & 0 \\ 0 & \lambda_{42} & 0 & 0 \\ 0 & 0 & \lambda_{53} & 0 \\ 0 & 0 & \lambda_{63} & 0 \\ 0 & 0 & \lambda_{73} & 0 \\ 0 & 0 & \lambda_{83} & 0 \\ 0 & 0 & \lambda_{93} & 0 \\ 0 & 0 & \lambda_{103} & 0 \\ 0 & 0 & \lambda_{113} & 0 \\ 0 & 0 & \lambda_{123} & 0 \\ 0 & 0 & \lambda_{133} & 0 \\ 0 & 0 & \lambda_{143} & 0 \\ 0 & 0 & \lambda_{153} & 0 \\ 0 & 0 & 0 & \lambda_{163} \\ 0 & 0 & 0 & \lambda_{173} \\ 0 & 0 & 0 & \lambda_{183} \\ 0 & 0 & 0 & \lambda_{193} \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \\ \varepsilon_8 \\ \varepsilon_9 \\ \varepsilon_{10} \\ \varepsilon_{11} \\ \varepsilon_{12} \\ \varepsilon_{13} \\ \varepsilon_{14} \\ \varepsilon_{15} \\ \varepsilon_{16} \\ \varepsilon_{17} \\ \varepsilon_{18} \\ \varepsilon_{19} \end{bmatrix} \qquad \begin{bmatrix} x_{11} \\ x_{21} \\ x_{31} \\ x_{41} \end{bmatrix} = \begin{bmatrix} \lambda_{11} & 0 & 0 & 0 \\ \lambda_{21} & 0 & 0 & 0 \\ \lambda_{31} & 0 & 0 & 0 \\ 0 & \lambda_{42} & 0 & 0 \\ 0 & 0 & \lambda_{53} & 0 \\ 0 & 0 & \lambda_{63} & 0 \\ 0 & 0 & \lambda_{73} & 0 \\ 0 & 0 & \lambda_{83} & 0 \\ 0 & 0 & \lambda_{93} & 0 \\ 0 & 0 & \lambda_{103} & 0 \\ 0 & 0 & \lambda_{113} & 0 \\ 0 & 0 & \lambda_{123} & 0 \\ 0 & 0 & \lambda_{133} & 0 \\ 0 & 0 & \lambda_{143} & 0 \\ 0 & 0 & \lambda_{153} & 0 \\ 0 & 0 & 0 & \lambda_{163} \\ 0 & 0 & 0 & \lambda_{173} \\ 0 & 0 & 0 & \lambda_{183} \\ 0 & 0 & 0 & \lambda_{193} \end{bmatrix} \xi_1 + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \end{bmatrix}$$

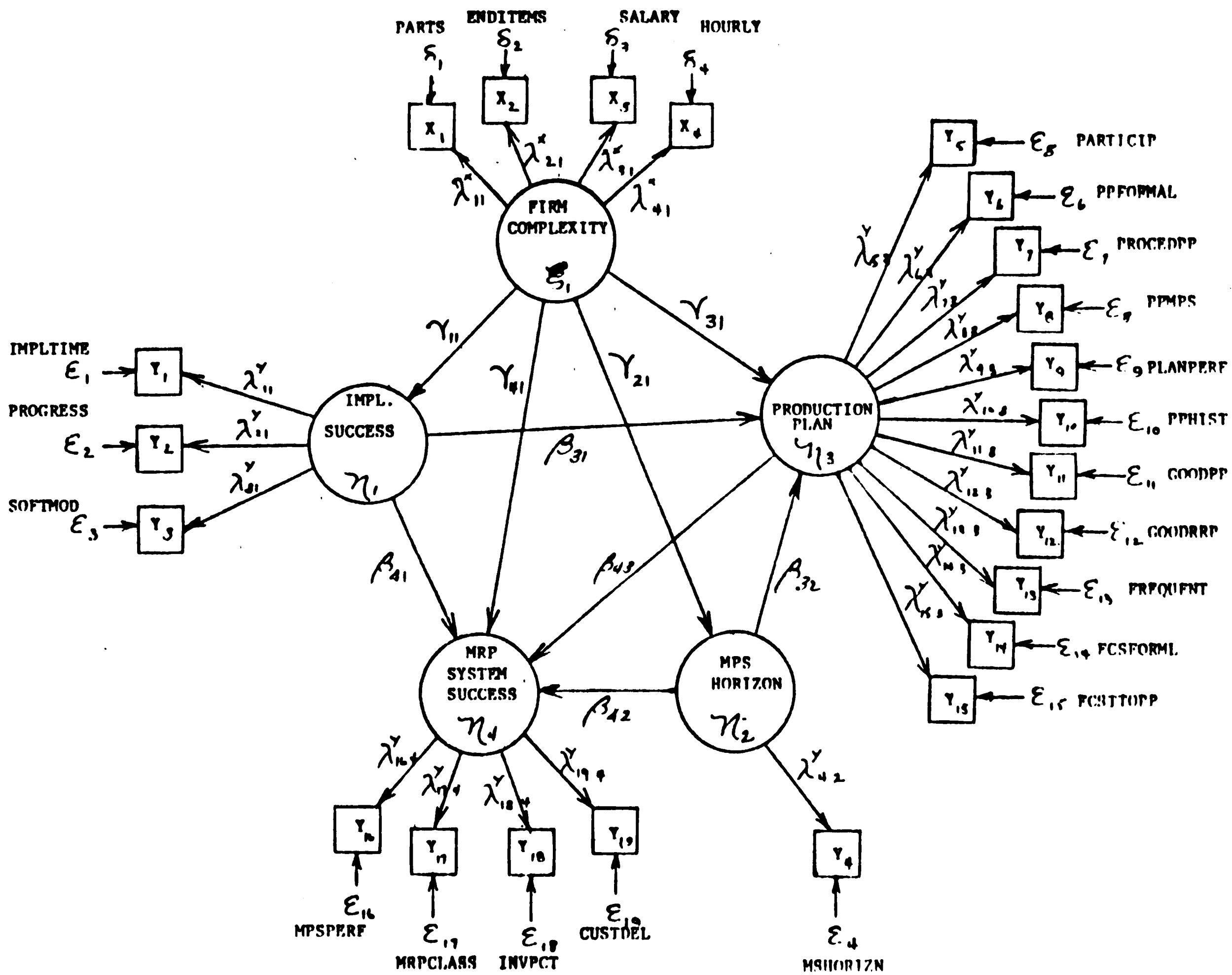

FIGURE 4-1

FIVE VARIABLE MODEL

A reduced model was ultimately used in the final analysis of the data. This reduced model is presented in Figure 4-2. The equations for this model follow.

$$\begin{bmatrix} 1 & 0 \\ -\beta_{23} & 1 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \\ y_{10} \\ y_{11} \\ y_{12} \\ y_{13} \\ y_{14} \\ y_{15} \end{bmatrix} = \begin{bmatrix} \lambda_{11} & 0 \\ \lambda_{21} & 0 \\ \lambda_{31} & 0 \\ \lambda_{41} & 0 \\ \lambda_{51} & 0 \\ \lambda_{61} & 0 \\ \lambda_{71} & 0 \\ \lambda_{81} & 0 \\ \lambda_{91} & 0 \\ \lambda_{101} & 0 \\ \lambda_{111} & 0 \\ 0 & \lambda_{122} \\ 0 & \lambda_{132} \\ 0 & \lambda_{142} \\ 0 & \lambda_{152} \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \epsilon_4 \\ \epsilon_5 \\ \epsilon_6 \\ \epsilon_7 \\ \epsilon_8 \\ \epsilon_9 \\ \epsilon_{10} \\ \epsilon_{11} \\ \epsilon_{12} \\ \epsilon_{13} \\ \epsilon_{14} \\ \epsilon_{15} \end{bmatrix}$$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} \lambda_{11} & 0 \\ \lambda_{21} & 0 \\ \lambda_{31} & 0 \\ \lambda_{41} & 0 \\ \lambda_{51} & 0 \\ \lambda_{61} & 0 \\ \lambda_{71} & 0 \\ \lambda_{81} & 0 \\ \lambda_{91} & 0 \\ \lambda_{101} & 0 \\ \lambda_{111} & 0 \\ 0 & \lambda_{122} \\ 0 & \lambda_{132} \\ 0 & \lambda_{142} \\ 0 & \lambda_{152} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \end{bmatrix}$$

The LISREL VI program of Joreskog and Sorbom (1985) was used to evaluate the above models given the data provided by the survey.

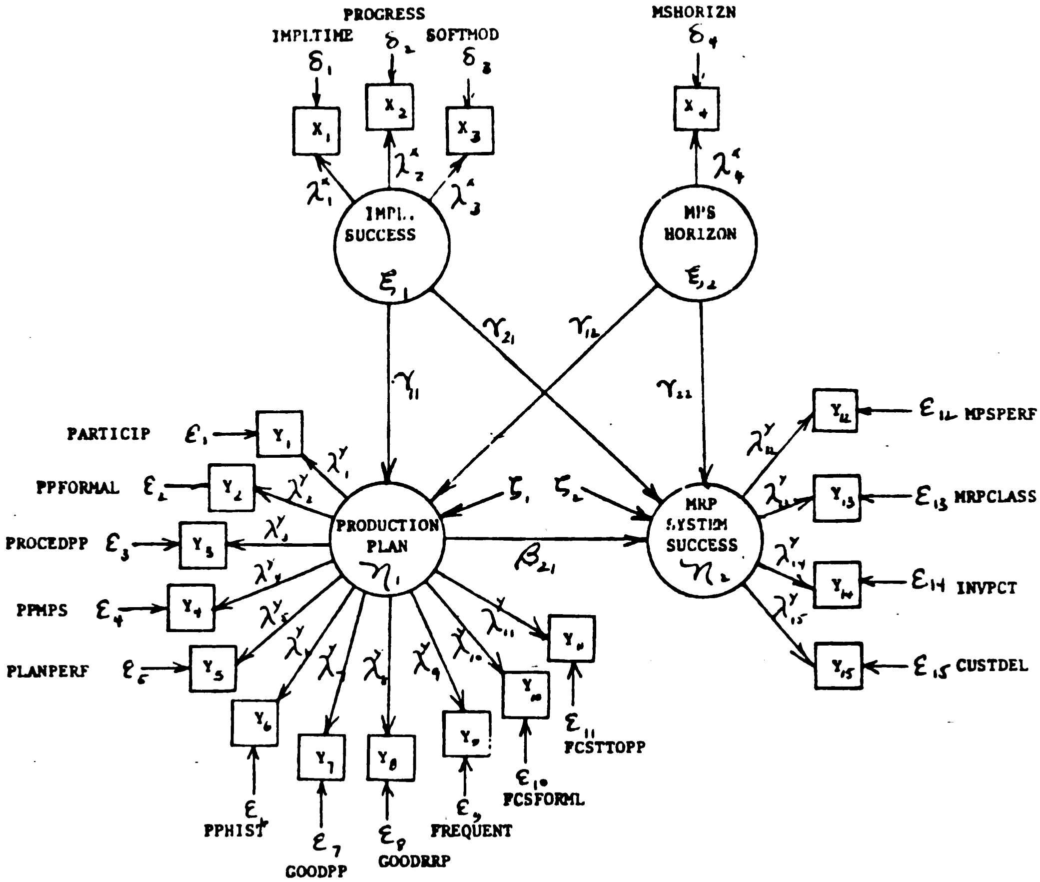

FIGURE 4-2

FOUR VARIABLE MODEL

Summary

The data analysis sought to not only test the hypotheses of the study but also to determine if bias in the sample existed. Bias was tested for by examining the smaller production plan sample against the full (all responses) sample to determine if differences existed which may affect the results. After this the hypotheses were tested primarily by the use of LISREL VI. A discriminant analysis was performed to test the hypothesis that firms with a production plan outperform those without a production plan.

Technical details and complete results are given in detail in Chapter 5 following and it is to these results that we now turn.

CHAPTER 5

RESEARCH FINDINGS

The research findings can be broadly categorized into four sets of results consistent with the methodological plan outlined in the previous chapter. First are the results of the general analysis of respondent, company profiles and other frequency information. In this section, the issue of bias is explored along with insights that the data provides concerning the hypotheses. Next are the results of the Pearson correlation analysis also intended to explore issues of bias. Then the results of the discriminant analysis related to the fundamental hypothesis that firms with production plans outperform those without are reported. Finally, results of the LISREL analysis are given which deal with the remaining hypotheses on the constituent characteristics of the production plan and the influences of the confounding variables.

Overview and General Analysis Results

As indicated earlier, 2500 questionnaires were mailed over a two month period. Of these, 276 were returned. Of these, 245 were usable. These provide the basis of the analysis. When data was missing on specific questions on the questionnaire, missing values were ignored and the remaining information for each question was analyzed. In some cases, notably the discriminant analysis, if any of the cases had missing data, the entire case was deleted by the program (SPSSX, 1985). When missing case information was significant, it is noted in the analysis that follows. Since the final LISREL analysis was done only with those companies with production plans, the data in that section is compared to the subset of data for those companies without a production plan.

The questionnaire requested the title of the respondent. For the whole sample, there were 242 responses. Titles ranged over ten categories. The most frequent respondent was from the materials area representing 128 or 52.9 percent of the sample (see Table 5-1). In the case of those companies with production plans (hereafter referred to as the PP sample), 85 of 158 or 53.8 percent of the respondents were from the materials area. It appears that the advice given on the cover page that,when in doubt, the materials manager should be requested to answer, probably helped to identify this respondent.

The next largest respondent groups for both the whole sample and the PP sample were from the information systems area and the operations/production area. These two respondent sources accounted for for 27.7 percent of respondents in the case of the full sample and 25.2 percent in the case of the PP sample. Thus 80.6 percent of the respondents in the case of the full sample and 78.2 percent of the PP sample came from these three categories.

As indicated earlier 96 firm SIC (standard industrial classification) codes were represented in the full sample while 79 codes were represented in the case of the PP sample (see Table 5-2). While it is unlikely that substantial bias has been introduced into the analysis because of non-respondents from the 17 industries, the non-respondent

TABLE 5-1

TITLE OF RESPONDENT

Function	Full Sample	Production Plan Sample
Materials	52.9%	53.8%
Information Systems	16.1	12.7
Manufacturing	11.6	12.7
Corp. Mgt.	5.0	6.3
MRP Project	4.1	4.4
Other	10.3	10.1

TABLE 5-3

TYPE OF FACILITY

Type	Full Sample	Prod. Plan Sample
Single Plant	60.1 %	57.5 %
Multiple Plants	39.1	41.9
Other	.8	.6

TABLE 5-5

PRODUCTION TYPE

Type	Full Sample	Prod. Plan Sample
Make-to-stock	73.1	79.4
Make-to-order	73.1	70.6
Assemble-to-order	46.5	30.0
Engineer-to-order	41.2	43.1

TABLE 5-2

INDUSTRIES REPRESENTED

Standard Industrial Classification Code	Responses Full Sample	P/P Sample
2024	1	1
2043	1	
2099	2	1
2295	2	
2389	1	1
2399	1	1
2431	1	
2434	1	1
2499	3	3
2519	1	
2522	2	2
2533	1	1
2649	4	1
2699	1	1
2732	1	1
2821	1	1
2833	1	
2834	6	5
2899	4	3
3011	1	1
3069	1	1
3143	1	1
3251	1	1
3299	1	
3316	1	
3325	2	1
3351	1	1
3354	1	1
3423	1	
3429	4	1
3432	1	1
3446	1	1
3451	1	1
3489	4	3
3494	4	3
3496	3	1
3499	15	9
3512	1	1
3523	3	2
3531	2	2
3533	3	1
3541	2	1
3542	3	2
3549	1	
3559	7	4
3561	6	6

TABLE 5-2 CONTINUED

Standard Industrial Classification Code	Responses Full Sample	P/P Sample
3562	3	1
3566	2	1
3568	1	
3569	3	1
3573	8	7
3579	1	1
3585	2	2
3586	1	1
3599	5	5
3612	1	1
3621	1	1
3622	5	3
3624	1	
3631	1	
3639	1	1
3648	2	2
3661	2	2
3662	1	1
3671	1	1
3673	2	1
3674	3	1
3678	1	
3679	6	2
3693	2	1
3699	9	8
3711	1	1
3713	1	
3714	7	5
3728	3	3
3743	1	1
3769	7	2
3799	2	2
3811	5	3
3823	5	3
3824	2	1
3829	6	4
3832	4	2
3841	8	5
3842	1	1
3843	1	
3861	1	1
3899	1	1
3914	1	
3931	1	1
3944	1	1

TABLE 5-2 CONTINUED

Standard Industrial Classification Code	Responses Full Sample	P/P Sample
3949	1	1
3951	1	
3993	1	1
3998	1	1
3999	4	4
Total	239	157

industries were investigated. In every case, while a specific respondent in an industry was missing there were still numerous examples from each manufacturing group in the PP sample. For example, in the primary metal industries, the sample was reduced from five firms to four and in the machinery group the same was reduced from 54 to 52 companies.

The largest majority of the respondents reported on single plants for both the full sample (60.1 percent) and the PP sample (57.5 percent). See Table 5-3 for a summary of the responses. The next highest response were those respondents reporting on multiple plant implementations: 39.1 percent for the full sample and 41.9 percent for the PP sample. In the case of the multiple plants, respondent data was usually reported in aggregate or for only the operation known well to the respondent.

Company sales for the full sample ranged from \$2 million to over \$10 billion with a mean of \$744 million and in the PP sample from \$3 million to over \$10 billion with a mean of \$908 million (see Table 5-4). Median sales for the full sample was \$90 million and for the reduced, PP sample was \$130 million.

Facility sales (the same as company sales for the single firm) were reported as ranging from \$1 million to \$9 billion with a mean of \$177 million for the full sample and from \$3 million to \$9 billion with a mean of \$173 million for the PP sample. Median sales for each were \$50 million and \$60 million for the full sample and the PP sample respectively. Both samples appear to offer a wide spectrum of company size and not much is lost in the reduced sample. However, the PP sample represents larger firms on average. This relates to the

TABLE 5-4

SALES
(in $ millions)

	Company Sales		Facility Sales	
	Full Sample	P/P Sample	Full Sample	P/P Sample
Mean	744	908	177	173
Median	90	130	50	60
Min	2	3	1	3
Max	> 10000	> 10000	9000	9000

TABLE 5-7

PART NUMBERS

	End Items		Parts	
	Full Sample	P/P Sample	Full Sample	P/P Sample
Mean	3192	2950	30929	33374
Median	500	500	12000	12000
Std. Dev.	10840	9915	104402	102206
Min	2	7	15	15
Max	> 100000	> 100000	> 1000000	> 1000000

made on the relationship between two of the constructs namely, that larger more complex firms are more likely to have production plans.

Most of the companies which responded to the questionnaire had more than one type of operation (Table 5-5). 73.1 percent of the companies in the full sample identified themselves as make-to-stock and 73.1 percent (not the same ones) identified themselves as make-to-order. 46.5 percent said they were assemble-to-order and 41.2 percent said they were engineer-to-order. For the PP sample, the response was 79.4 percent make-to-stock, 70.6 percent make-to-order, 30 percent assemble-to-order and 43.1 percent engineer-to-order. The reduced sample seems to be consistent with the full sample.

Volume/process information was requested from each firm. Most of the firms identified themselves as having more than one process such as those who reported both job shop and repetitive activities (Table 5-6). Within each process type, volume was identified as low, medium or high. For the full sample, those respondents which identified themselves as having a job shop process were evenly divided as to volume: 35 percent low, 35 percent medium and 30 percent high. In the PP sample results were nearly identical. For the full sample 56.7 percent of the companies identified themselves as job shop or having some job shop component while in the PP sample, 53.8 percent responded in this manner. Again, the samples are roughly similar and little bias is expected.

The results for the remaining three process types was similar. In the full sample, 61.2 percent identified themselves as batch operations with 44 percent reporting medium volume. In the PP sample 60.6 percent were batch and 46.4 percent reported medium volumes.

TABLE 5-6

MANUFACTURING PROCESS/VOLUME

	Job Shop		Batch		Repetitive		Continuous	
	Full	P/P	Full	P/P	Full	P/P	Full	P/P
% of Total Responding	56.7	53.8	61.2	60.6	56.3	51.9	27.8	30.0
% Low Vol.	35	34	26	24	31	30	62	58
% Med. Vol	35	35	44	46	33	37	22	25
% High Vol.	30	31	30	30	36	33	16	17

For repetitive operations, 56.3 percent of the full sample reported this type of activity as compared to 51.9 percent for the PP sample. In each case, volume was evenly divided between low, medium and high.

The number of firms reporting themselves as continuous operations or having some continuous operations aspects was considerably smaller: 27.8 percent for the full sample and 30 percent for the PP sample. It is highly likely that those firms are referring to some continuous type operation which is part of their total operation rather than being primarily continuous since most all who reported themselves as continuous also reported some other process type for the firm and only 4.5 percent of the full sample and 5.0 percent of the PP sample reported high continuous volume.

The firm complexity construct referred to above as part of the LISREL model is represented by both the number of end items that the firm master schedules and the number of parts controlled in the system (Table 5-7).

For the full sample, the number of end items ranged from two to more than 100,000 with a mean of 3192 and a standard deviation of 10840. For the PP sample, the number ranged from seven end items to more than 100,000 with a mean of 2950 and a standard deviation of 9916. The difference is probably due to the fact that the full sample has eighteen firms with 10,000 or more end items and four with 50,000 or more while the PP sample has only ten firms with 10,000 or more end items and only two with more than 50,000 end items. The median for the full sample and the PP sample is 500 end items. About 93 percent of the respondents are below 10,000 end items for both samples and again no bias is expected by use of the reduced sample.

The full sample reported a range of total parts in the system from fifteen to over one million, a mean of 30,929, a standard deviation of 104,402 and a median of 12,000 parts. The PP sample had the same range, a mean of 33,374, a standard deviation of 102,206 and a median also of 12,000 parts. Again, based on these statistics, not much bias is expected to be introduced by use of the smaller sample.

Implementation time is another critical variable used in the LISREL model. The full sample reported implementation times ranging from just starting, to times of more than eight years (see Table 5-8). The PP sample had the same range. The mean was 33 months for the full sample and 34 months for the PP sample. The standard deviations were both about the same at a little over two years. The median was 26 months for both. Again, the reduced sample is remarkably similar to the full sample. It is interesting to note that the average implementation time is slightly less than three years while many consultants continue to talk about eighteen to twenty-four months as the standard (see for example standard literature produced by Comserv for its AMAPS system).

The number of salaried and number of hourly employees are the other two measures of the firm complexity construct. The full sample reported from three to 4,000 salaried with a mean of 276 and a standard deviation of 490 (see Table 5-9). The PP sample ranged from five to 4,000 with a mean of 308 and a standard deviation of 528. The median for the full sample was 130 while the median for the reduced sample was 150. It appears that the reduced sample represents more companies

TABLE 5- 8

IMPLEMENTATION TIME

(in months)

	Full Sample	Prod Plan Sample
Mean	33	34
Median	26	26
Std. Dev.	27	25
Min	0 (just starting)	0 (just starting)
Max	> 100	> 100

TABLE 5-9

NUMBER OF EMPLOYEES

	SALARIED		HOURLY	
	Full	P/P	Full	P/P
Mean	276	308	509	543
Median	130	150	250	300
Std. Dev.	490	528	1013	990
Min	3	5	9	10
Max	4000	4000	> 10000	> 10000

with a larger number of salaried employees. It is not clear what bias, if any, has been introduced but it appears that larger companies are more likely to have production plans as was noted above.

The number of hourly employees for the full sample ranged from nine to more than 10,000 with a mean of 509 and a standard deviation of 1,013. In the case of the reduced PP sample, the range was from ten to over 10,000 with a mean of 543 and a standard deviation of 990. The median for the full sample was 250 and for the PP sample was 300. Again, the reduced sample tends to capture those companies with a higher work force and the same tentative conclusions as those above may be stated.

One of the concerns expressed earlier was that those companies which developed MRP software in-house may not be captured in the sample. When asked about software modification, fully 22.3 percent of the full sample and 21.9 percent of the PP sample reported software that was wholly developed in-house (see Table 5-10). It is difficult, if not totally impossible to determine the ratio of in-house developed software to that of purchased software for the entire population and therefore it cannot be determined if the sample is biased toward those who developed software in-house. The distribution of cases through the range of software modification from none to completely developed in-house was nearly identical for the two samples. This measure is part of the implementation success construct.

A series of questions was asked concerning each of the software modules generally available in most MRP packages. Implementation

TABLE 5-10

DEGREE OF SOFTWARE MODIFICATION
(% of total)

	Full Sample	Prod. Plan Sample
no modification	14.4	13.5
some modification	36.2	36.8
a great deal of mod.	27.1	27.7
developed in house	22.3	21.9

progress was judged by the number of modules which were implemented and being used regularly. The results, shown in Table 5-11, were as follows.

Fifty-four percent of the full sample reported having a forecasting module but only 38 percent reported using the module regularly. Of those who did, more than half did forecasting monthly. For the PP sample, 57 percent had the module, 41 percent used it and more than half also forecasted monthly. The slight increase in use may not be significant or it may show that companies with production plans are more likely to do forecasting as one of the original hypotheses indicates. A better determination will be made in the LISREL analysis.

Software with rough cut capacity planning modules were reported in 62 percent of the full sample as against 68 percent of the reduced sample. Regular use of the module was reported in 43 percent of the full sample and 47 percent of the PP sample. Again the increase may not be significant but it may also support the earlier hypothesis about production planning. About a quarter of the sample reported doing rough cut planning weekly and about a third reported doing it monthly for both samples. Since, as stated earlier, rough cut capacity planning is usually done in conjunction with the master schedule (Vollmann, Berry and Whybark, 1985), one would expect it to be done weekly which is what was reported for master schedule frequency as will be seen next.

The master schedule and the material requirements planning modules are the heart of the MRP system and a large portion of the respondents were expected to indicate such systems both present in

TABLE 5-11

MRP SYSTEM FEATURES AND USE

	Forecast.		Rough Cut Cap Plan.		MPS		Prod. Plan		Purch.		SFC		MRP		CRP	
	Full	P/P	Full	P/P	Full	P/P	Full	P/P	Full	P/P	Full	P/P	Full	P/P	Full	P/P
Have Feature	54	57	62	68	80	83	63	69	78	82	70	70	86	89	65	67
Use Regularly	38	41	43	47	68	74	49	58	72	78	58	62	78	83	45	47
Frequency On-line									15	13	10	8	12	10		
Daily					14	14			49	54	65	69	16	18	10	11
Weekly	16	16	26	20	55	53	31	29	27	24	18	16	56	58	56	58
Monthly	57	55	35	36	16	16	35	36							13	9

the software and in use regularly. For the full sample 80 percent reported having master schedule software while 83 percent replied positively for the reduced sample.

The number who used the master schedule regularly was significantly higher for the reduced sample at 74 percent compared to the full sample at 68 percent. In both samples MPS (master production schedule) frequency was weekly in over half the cases.

Next, the respondent was asked if his/her system had a production planning module. No definition was offered for production planning at this point in the questionnaire and there are few commercial packages which have a production planning module as part of their MRP II packages. A problem of interpretation arises here. If the respondent interprets the question as asking if he/she has a production planning software module then the responses to this question will not be consistent with the latter question which asks if the respondent has a production plan when a definition of the plan is provided. If on the other hand, the respondent interprets the question as asking if he/she has a production plan (but not necessarily a software module), the answer is expected to be consistent with the response to the latter question. Sixty-three percent of the full sample reported having a plan. While this is roughly consistent with the 65 percent of the total sample who reported having a production plan in the latter question (after a definition was provided), only 69 percent of the PP sample reported having a plan, clearly inconsistent. The question was meant to provide an internal validity check but because of interpretation problems, it cannot be used as such.

The purchasing module is often included in the standard MRP software package and 78 percent of the full sample reported having one while 82 percent of the PP sample reported its presence. Seventy-two percent and 78 percent reported using this module regularly for the full and reduced samples respectively. Both samples reported updating daily as the norm. Again, usage of the module increases with those who have production plans perhaps indicating greater progress in implementation as hypothesized.

Shop floor control modules are also often offered as part of the standard MRP software system. Seventy percent of the full sample and the reduced sample reported having them. But, 62 percent of the reduced sample reported using them regularly as against 58 percent of the full sample. Two-thirds of both samples said they update or replan daily.

Eighty-six percent of those reporting indicated the presence of a material requirements planning module in the full sample. This was true of 89 percent of the PP sample. Seventy-eight percent and 83 percent of the full and reduced samples respectively used the module regularly. The module was updated or replanned on-line daily and weekly in 84 percent of the cases in the full sample and 86 percent of the cases in the reduced sample. In both cases, two-thirds of these "ran" MRP weekly. The percent of use continues to be higher in the reduced sample perhaps indicating better systems.

The use of capacity requirements planning, generally done in conjunction with material requirements planning, was considerably lower than that of material requirements planning. Those in the full sample reported having such a module 65 percent of the time but used it regularly only 45 percent of the time. In the PP sample, 67 percent reported having the module and 48 percent reported using it regularly. For those that used it, over half did so weekly. This equates well with the use of the material requirements planning module.

The internal lead time of the product was defined as the time it takes to produce a product with all purchased items available. For the full sample, internal lead times varied from one week to over 100 weeks with a mean of 8.3 weeks, a standard deviation of eleven weeks and a median of six weeks (see Table 5-12). The reduced sample ranged from one to eighty weeks with a mean of 7.3 weeks, a standard deviation of 8.5 weeks and a median of six weeks also. There appears to be a shorter lead time and a tighter distribution in the reduced sample. Further examination shows that many of those companies with longer lead times were not in the reduced sample. This may bias the smaller sample toward those companies with shorter internal lead times. It is difficult to determine the nature of the bias. One explanation for the difference may be that those companies with production plans also have better systems enabling them to reduce internal production lead times. Of course, this same result could be obtained simply randomly.

The same pattern is true with total lead time (defined as including the lead time for purchased items), but the differences are less. Again the medians are both the same at sixteen weeks.

Next, respondents were asked about the time horizon covered by their master schedules. It was important to compare these to the total lead times since a good master schedule (as defined earlier) should cover the cumulative (total) lead time of the product. MPS

TABLE 5-12

LEAD TIMES
(weeks)

	Internal		Total	
	Full	P/P	Full	P/P
Mean	8.3	7.3	25	24
Median	6	6	16	16
Std. Dev.	11	8.5	26	23
Min	1	1	2	2
Max	100	80	150	130

TABLE 5-13

MASTER SCHEDULE HORIZON
(weeks)

	Full Sample	Prod. Plan Sample
Mean	54	51
Median	52	52
Std. Dev.	77	42
Min	1	3
Max	1000	260

horizons ranged from one week to over 1,000 weeks (for one company) while for the reduced sample, they ranged from three weeks to 260 weeks (5 years). Master schedules covering five to ten years in length are difficult to imagine and it must be concluded that there is some difficulty with the definition of what a master schedule is. Unfortunately, none was offered in the questionnaire and this is now considered a drawback. The mean MPS horizon is 54 weeks for the full sample and 51 weeks for the reduced sample (see Table 5-13). Standard deviations are 77 and 42 weeks respectively. The medians are 52 weeks for both and in both cases about a third of the companies reported using a horizon of 52 weeks. This is generally consistent with a kind of "standard practice" for master schedule operation.

The next section of the questionnaire dealt with a variety of system success measures. The results are shown in Table 5-14 and are discussed below. The first of these was the Ollie Wight MRP system class. The respondent was asked to decide what class MRP system he/she believed their system to be. The characteristics of each class were carefully described (see the questionnaire). The traditional four point scale of A, B, C or D was extended to ten points to allow for pluses and minuses in the evaluation as is often done. The mean of the full sample was 4.77 or between a C+ and B-. The mean for the reduced sample was 5.45 or somewhere between a B- and a B. The median was a five for both. It may be that the reduced sample shows better average performance because of having better systems (with a production plan) or it may be random. This will be explored further in the other statistical analyses.

TABLE 5-14

SYSTEM PERFORMANCE

	MRP Class		MPS Performance		Inv. Performance		Cust. Del. Performance	
	Full	P/P	Full	P/P	Full	P/P	Full	P/P
Mean	4.77	5.45	82.4%	85.4%	87.0%	88.0%	84.5%	89.3%
Median	5	5	85	88	90	90	90	90
Std. Dev.	2.6	2.4	19.6	13.6	11	10	14.2	10.4
Min	0	0	9	25	50	60	20	36
Max	9	9	100	100	100	100	100	100

Master schedule performance was defined as the percent completion of the master schedule to what was planned, on average, over the last three planning periods. For the full sample, answers ranged from nine percent completed to schedule on average to 100 percent. For the reduced sample, responses ranged from 25 percent to 100 percent. Means were 82.4 percent and 85.4 percent respectively. The medians were 85 percent and 88 percent for the two samples. While it appears that those with production plans outperform those without, the large number of responses with estimated performance numbers confounds this analysis.

Respondents were asked to indicate how often inventory goals were set for their facility. This and the next two questions were designed to identify inventory "performance." Answers ranged from zero meaning they are not set to 52 weeks (set yearly) for the full sample and the reduced sample (see Table 5-15). Means were 19 and 18 weeks respectively and medians were 12 weeks (quarterly) for both. Thirty-two percent of the full sample indicated monthly goal setting, 23 percent indicated goals were set quarterly and 23 percent indicated an annual activity. The results were similar for the reduced sample but with slightly higher percentages monthly and quarterly and slightly lower percentages yearly. More frequent review of inventory goals is consistent with production planning since one of the purposes of production planning, as stated earlier, is to set the level of inventories and/or backlogs.

The respondents were also asked in what units inventory goals were set. Seventy-three percent of the full sample responding said goals were set in dollars and 61 percent indicated they were set in terms of

TABLE 5-15

FREQUENCY OF INVENTORY GOAL SETTING
(weeks)

	Full Sample	Production Plan Sample
Mean	19	18
Median	12	12
Std. Dev.	19.5	18.8
Min	1	1
Max	52	52

TABLE 5-16

INVENTORY GOALS SET IN TERMS OF

	Full Sample	Production Plan Sample
Dollars	72.9%	66.4%
Turns	60.6	65.1
Other	8.3	10.7

inventory turns (see Table 5-16). For the reduced sample, responses were 66 percent and 65 percent respectively. Clearly, many respondents used both measures. No bias is expected in the reduced sample based on the differences between the responses of the two groups.

Inventory performance was requested in terms of percent achievement to goals. This was considered to be an important indicator of overall system performance, but has a number of inherent problems. Primary among those problems is the extent to which the goals set were achievable. If inventory goals are unrealistic, the likelihood of achieving them will be considerably reduced. Beyond this consideration, there must be capability to achieve the goals.

The questionnaire does not deal with these issues since they are very complex and ultimately involve value judgments which can easily be different from the viewpoints of the researcher and the respondent. The responses received were quite often estimated leading to the conclusion that a certain amount of measurement error will be present. This can best be estimated in the LISREL analysis.

The full sample had a mean performance level of 87.4 percent, a standard deviation of 10.7 percent and a median of 90 percent with nearly 27 percent of the respondents reporting performance at the 90 percent level.

The reduced sample had a mean of 88.3 percent, a standard deviation of 10.6 percent and a median of 90 percent. 28.5% of these respondents reported a 90 percent performance level. The differences are too slight to conclude that those with production plans have better inventory performance.

Next, respondents were asked if the sales customer delivery performance is the same one as the manufacturing customer delivery performance. The question was asked based on the belief that, in the better run systems, customer delivery performances are based on a master schedule which both sales and manufacturing participate to develop a single promise.

In the full sample 79.2 percent of the respondents indicated the same promise was used. In the reduced sample 83.7 percent indicated that the same promise was used. This would seem to indicate that those with production plans are more likely to use a single promise based perhaps on the master schedule.

For those who used a single promise, respondents were asked to indicate what their customer delivery performance was in percent of on-time delivery to promise. The full sample reported an average performance level of 86.5 percent, a standard deviation of 14 percent and a median of 90 percent which was also the mode. For the reduced sample, the mean was reported as 89.3 percent with a standard deviation of ten percent, a median of 90 percent also and two significant modes of 90 and 98 percent. It appears from this data that those with production plans performed above those without. This issue is dealt with in much more detail in the LISREL analysis.

For those companies which did not use the same promise, performance was measured to the sales promise and to the manufacturing promise separately. Often, when poorer systems are present, manufacturing and sales will each make their own promises and track their own results. Unfortunately, the customer is the one who suffers in these circumstances and reduced customer delivery performance generally results from this in-fighting. Further, multiple promises are often made and it is difficult to determine which promise is being used to measure on-time delivery. Clearly both groups will claim performance superiority or blame problems on the other. This scenario is depicted in Oliver Wight's classic MRP work (1974).

For the full sample, only 15.9 percent of the respondents indicated that sales promises were made independently of manufacturing (see Table 5-17). For these respondents, a mean on-time delivery performance of 77.6 percent was reported with a mode of 80 percent. For the reduced sample, 13.1 percent indicated a separate sales promise was made and the average performance level was 83.5 percent with a median of 85 percent.

For manufacturing promises, the full sample reported a mean of 84.1 percent and a median of 85 percent while the PP sample mean was 86.9 percent and the median was also 85 percent. There are two tentative conclusions. First, it is not surprising that customer delivery performance for those companies with a single promise is higher than for those with two groups promising. This is to be expected as the discussion above indicates. Second, a higher performance to manufacturing promise must be somewhat suspect since, in most cases, it is the materials group or manufacturing group which is answering the survey and they are likely to be biased in favor of manufacturing performance. Further, past experience indicates that sales, when not in close coordination with manufacturing, cannot make promises with great validity. Therefore, lower performance is to be expected from sales.

The remaining section of interest of the questionnaire is devoted to the production plan, its characteristics, procedures, etc.

TABLE 5-17

CUSTOMER DELIVERY PERFORMANCE
EVALUATED BY SALES AND MANUFACTURING WHEN
DIFFERENT PROMISES ARE USED BY BOTH

	Sales		Manufacturing	
	Full	P/P	Full	P/P
Percent Responding	15.9%	13.1%	16.7%	12.5%
Mean	77.6	83.5	84.1	86.9
Median	80	85	85	90
Std. Dev.	17.7	9.7	12.4	9.6
Min	10	60	50	69
Max	100	98	100	100

The total sample was made up of about 66 percent with a production plan and 34 percent without. It is the information from these 160 respondents with a production plan that are next reported. In a few cases, where questions applied to the whole sample (such as in the case of forecasting) the full sample results will also be reported.

One of the first questions asked was what the production plan was called in the respondent's company. This was an important question since two pieces of information can be obtained from it. First, even though a careful and complete definition of the production plan was given, it is clear from the responses that interpretation of the definition varied so widely that, in many cases, it is unclear if what is being reported is really a production plan as the definition indicated. For example, in one case, it was called an Annual Budget. It is difficult to imagine that an annual budget can be interpreted as a production plan. Since alternate definitions were not offered for some of these other names which may have enabled the respondent to be more accurate, exact conclusions cannot be drawn on what is meant by the respondent. Differentiation must be accomplished by the remaining questions and subsequent analyses. This reporting of name differences does however clearly illustrate the general uncertainty of the production plan and its characteristics which is indicative of nominclature problems typical to all relatively new technologies. A list of the various respondent names for their production plans can be found in Table 5-18.

Period of plan formulation and reformulation was previously indicated to be important to the overall operation of the plan. The distribution of responses for this variable called production plan

TABLE 5-18

TITLES GIVEN TO THE PRODUCTION PLAN

Operations Plan
Company Sales and Operating Plan
Game Plan Meeting
Master Schedule
Production Schedule
Budget
Production Forecast
Capacity Planning Analysis
Annula Operating Plan
Annual Operating Plan with Monthly updates
The Assembly MPS
Control Volume
Manpower Forecasting
Quarterly Forecast
Manufacturing Plan
Production, Inventory and Sales Plan
Line Item Contracts
Business Plan
Four Year Forecast
Priced Plan
Build Schedule
Master Plan
Manufacturing Forecast
Production Objectives
The Five Quarter Production Plan
Product Code by Family
Manufacturing Workload
Production Committed Plan
S & P
Forecasting Group
Sales Operation Plan
Financial Plan
Sales, Production and Inventory Forecast
Budget/Forecast Plan
Original Budget
Material or transfer Plan
Gross Master Schedule
Operational Plan
Forecast Review
Production/Inventory Plan
Unit Operating Plan
Build Plan
Shop Schedule
Planning Package
Fiscal Sales Forecast

frequency, showed a mean of 9.2 weeks, a standard deviation of .96 weeks a median of four weeks and a strong mode of 56 percent of all responses at four weeks (see Table 5-19). This information formed the basis of one of the measures of the plan and is described in full in the LISREL discussion below.

The plan horizon varied widely among respondents from four weeks to 300 weeks. The mean was 46 weeks with nearly 40 percent reporting a one year horizon which was also the median. This 52 week horizon is consistent with many of the case studies mentioned in the literature review.

The participants in the formulation and approval of the production plan for each functional area of the company were explored in the next question. In each case, the respondent was asked to identify the title of the representative from each functional group which participates in the plan. As stipulated above, the expectation is that the major functional areas of marketing/sales, production/operations, finance/accounting, R&D/design engineering and the COO will be the primary participants. Other areas which may also participate are materials and master scheduling. Results are shown in Tables 5-20 and 5-21 and are discussed below.

In the marketing/sales area, 87 percent of the respondents indicated that a marketing representative participated in the formulation of the plan while only 65 percent indicated that a marketing/sales representative approved the plan. Of those marketing/sales people who helped formulate the plan, nearly one-half were managers. For those who approved the plan, 43 percent were at the vice president level. In 8.7 percent of the cases, it was stated that marketing did not

TABLE 5-19

PRODUCTION PLAN CHARACTERISTICS

	Frequency of Planning	Prod. Plan Horizon
Mean	9.2 weeks	46.1 weeks
Median	4	52
Std. Dev.	12.1	38.1
Min	1	4
Max	52	300
Mode	4	52

TABLE 5-22

PER CENT OF RESPONDENTS FROM EACH FUNCTIONAL AREA WHO DID NOT PARTICIPATE IN PRODUCTION PLANNING

Marketing/Sales	8.7%
Production/Operations	4.4
Finance/Accounting	25.6
R & D/Engineering	55.6
Chief Operating Officer	21.2
Master Production Scheduler	18.8
Materials	11.9

TABLE 5-20

TITLE OF PERSON WHO PARTICIPATES IN PLAN PREPARATION

	Mkt/Sales	Prod./Ops	Fin/Acct	R&D/Eng	COO	Matls
Manager	51.8%	45.2%	16.1%	47.6%		77.3%
Director	12.2	9.6	8.6	9.5		9.2
Vice President or Controller	26.2	23.7	55.9	26.2	13.9	4.2
Chief Operating officer		3.7			63.9	
Supervisor	1.4	4.4	3.2	4.8		3.3

TABLE 5-21

TITLE OF PERSON WHO APPROVES PRODUCTION PLAN

	Mkt/Sales	Prod/Ops	Fin/Acct	R&D/Eng	COO	Matls.
Manager	22.1	24.8	9.4	25.0		51.1
Director	13.5	3.3	8.2	9.4		7.8
Vice President or controller	43.3	36.3	62.4	34.4	13.9	17.8
COO/President	11.5	14.4	12.9	21.9	63.9	14.4
Supervisor		.9		3.1		2.2

participate in either the formulation or approval of the plan (see Table 5-22).

In the case of manufacturing, 84.4 percent of the respondents indicated that a manufacturing representative was part of the formulation process. However, only slightly over 70 percent approved the plan. Forty-five percent of those who participated in the formulation were managers and 36 percent of those who approved the plan were vice presidents. Only 4.4 percent of the respondents said that production/operations does not participate in either plan formulation or approval.

There was a large fall off in representation in the planning activity in the finance/accounting area. Only 58 percent of the respondents indicated that there was a representative from finance or accounting in the formulation of the plan while only 53 percent participated in its approval. Almost 26 percent said that finance or accounting does not participate in either the formulation or approval of the plan. In both the formulation and the approval of the plan, the major participant was identified as the controller.

Since the role of finance/accounting in the production plan is to see to it that financial resources are in line with the plan and to assure that the plan meets the revenue goals of the firm as stated in the annual business plan, there are several possible explanations for non-participation. One of these is that the budget for the firm, which is a logical consequence of the business plan, acts as a constraint on the production planning process. Another is that some other function takes the place of finance/accounting in the planning process and accomplishes its functions. A third is that these functions are not getting done and as a consequence good plan performance will be subsequently far more difficult to achieve. The survey did not explore these issues.

The engineering department was very sparsely represented. Only about 26 percent of the respondents indicated that this group was represented in the planning process and only 29 percent indicated that engineering participated in the approval of the plan. More particularly, 55.6 percent specifically indicated that engineering did not participate in either the plan formulation or its approval.

Engineering participation would be particularly important in a high tech firm with a great deal of engineering activity or in a firm where many new products were regularly introduced. It is also possible that even under those circumstances, the role that engineering plays, guaranteeing the schedules of new product development and assuring the support of existing products, is handled routinely by another function like materials who interacts with engineering during the planning process. For those who did participate, the title of manager was most often cited for the formulation activity and vice president for the approval process.

In only 45 percent of the cases was the COO a participant in the formulation of the plan while in 64 percent of the cases the COO approved the plan. In 21 percent of the cases the COO was neither a participant nor an approver of the plan. The title of the COO were most often given as president but there were also a number of plant managers and vice presidents who occupied that role.

The master scheduler was a participant in the formulation of the plan in 64 percent of the cases but participated in the approval process only 32 percent of the time. This is consistent with the role of the Master Scheduler as translator, secretary and reporter of the plan. In only 19 percent of the cases was the master scheduler not a participant at all.

The materials function was reported as a participant in the formulation process in 75 percent of the cases and was in three quarters of the cases the materials manager. However, materials participation in approval occurred in only 56 percent of the cases and in over half of these cases it was the manager of materials who did so. Twelve percent of the respondents reported that the materials function did not participate at all in the planning process.

There were a variety of other functions which participated in the planning process. Most notable of these was the personnel function.

In summary then, the major participants in the production planning process were from the marketing/sales, operations/production and the materials function. Participating less often were the COO, finance/accounting and master scheduler. The lowest level of participation was the R&D/engineering function. It is expected that those companies where all of the functions participate will be better performers and be associated with better, more successful systems. This will be tested in the LISREL analysis below.

Two additional measures of the production plan are its formality and the presence of controlling procedures. These measure the extent to which the process is ingrained in the regular operation of the total manufacturing control system and are reported in Table 5-23.

In the case of formality, 58 percent of the respondents indicated that the production plan was very formal and always written.

TABLE 5-23

PRODUCTION PLAN FORMALITY

3.2%	3.2%	13.9%	20.3%	58.9%
Very Informal Usually sent Verbally		Somewhat formal Sometimes Written Sometimes Verbal		Very Formal Always Written

Mean	4.3
Std. Dev.	1

TABLE 5-24

PRODUCTION PLAN PROCEDURES

2.0%	4.7%	20.8%	44.3%	28.2%
No Procedures		Some Procedures Irregularly Followed		Strict Procedures Always Followed

TABLE 5-25

FUNCTIONS WHICH USE THE PRODUCTION PLAN

Production/Operations	55%
Marketing/Sales	34
Finance/Accounting	33
R & D/Engineering	22
Materials	40
Other	25

The measure of formality was on a five point Likert scale. The mean was 4.3, the standard deviation was one and the median as well as the mode was five (very formal, always written).

In terms of procedures, the ranking was also done on a five point Likert scale rated from no procedures to strict procedures, always followed. The responses in this case (Table 5-24) were not as strong. The mean was 3.9, the standard deviation, .9 and the median and mode was four.

It was expected that those with better plans will more often have formal plans and strict procedures.

As was indicated earlier, the production plan is meant to be the controlling influence on the master schedule and the master scheduler has the authority to schedule to the rates approved by the production plan. In that regard, the respondents were asked if the master scheduler receives the production plan and if the plan is used to prepare the master schedule.

Eighty-five percent of the respondents indicated that the plan was received by the Master Scheduler and 82 percent indicated that the master scheduler does use the plan in preparing the master schedule.

The production plan is often used by other departments for various purposes. The respondents were asked to identify which other departments or functions used the plan (see Table 5-25). Fifty-five percent replied that the plan also went to the manufacturing area for a variety of purposes. Thirty-four percent indicated that the plan went to marketing/sales. Thirty-three percent indicated that finance/ accounting received a copy. Twenty-two percent said that R&D/ engineering received a copy. Forty percent said that materials received a copy and only eight percent said that upper management received a copy. Except for upper management, the results are consistent with the level of participation in the formulation and approval of the plan.

One of the important characteristics of the plan is the degree to which the plan is achieved on a regular basis. Plans which are achieved on a regular basis are expected to be indicative of better plans and better planning systems. Seventy-five percent of the respondents indicated that they regularly measured the performance of the plan. Of these, plan performance averaged 90.9 percent over the past three planning periods. The median performance level was 92 percent. Estimates ranged from 70 percent to 130 percent. Clearly, when 130 percent of the plan is achieved, one must believe that this is no better than 70 percent since producing more than the plan implies disproportionate consumption of resources and perhaps excessive expediting. Therefore, the data was reinterpreted so that any measure over 100 percent was taken as 100 percent minus the difference between 100 percent and the number reported over 100 percent. Thus, 107 percent was translated to 93 percent. This new distribution (Table 5-26) varied from 70 percent to 100 percent with a mean of 89.6 percent and a standard deviation of just under eight percent. The median was 90 percent which also garnered the most responses.

Respondents were also asked what measures the plan was stated. The most frequent response was that the plan was stated in units (70.1 percent) (see Table 5-27). Next most frequently was dollars with 52.6 percent of the respondents reporting this unit of measure. Next was hours or standard hours at 31.3 percent. There were a number

TABLE 5-26

PRODUCTION PLAN PERFORMANCE

Performance (%)	Percent Achieving Performance
70	4.1
72	.8
73	1.6
75	2.4
76	.8
77	.8
78	.8
80	4.1
82	1.6
83	3.3
84	.8
85	4.9
86	.8
87	4.1
88	4.9
89	.8
90	13.8
91	1.6
92	5.7
93	7.3
94	13.0
95	2.4
96	4.1
97	4.9
98	4.9
99	4.9
100	5.7

TABLE 5-27

PRODUCTION PLAN UNITS

Units	70.1%
Dollars	52.6
Std. Hrs.	31.3
Other	4.4

TABLE 5-28

PRODUCTION PLAN TERMS

Families	65%
Individual Products	35
Mix	11
Other	3

TABLE 5-29

PRODUCTION PLAN HISTORY
(in months)

Mean	82.6
Median	60.0
Std. Dev.	133.5
Min	0 (just started)
Max	480

of additional measures such as yield, families and efficiency. The numbers do not add to 100 percent since many respondents gave multiple answers. This question provided information only and was not used to analyze the plan.

In addition to the above information, it was determined that 65 percent of the respondents aggregated the plan in terms of families of products while 35 percent stated the plan in terms of individual products and 11 percent used some sort of mix to prepare the plan (see Table 5-28). Again the numbers do not add to 100 percent since some respondents indicated that the plan was stated in a number of different levels of aggregation.

The length of time that production planning was ongoing was felt to be significant; the longer that a company was doing production planning, the better the system might be. The range of answers ran from "just started" to over four years (see Table 5-29). There were several indeterminate answers like "as long as I can remember." These were omitted from the sample. The mean for this response was 80 months with a median of 60 months or five years. The largest number of responses indicated a two year history of production planning.

Resource requirements planning is hypothesized to be an important part of the production planning process. A definition of resource requirements planning was offered in the questionnaire. Fifty-eight percent of the respondents indicated that they did such planning. Of those, 37.4 percent indicated that this planning was done every four weeks (see Table 5-30). The mean was 10.3 weeks and the standard deviation was 13.8 weeks. The median was four weeks. This would be the ideal period since, to be effective, the resource planning should

TABLE 5-30

RESOURCE REQUIREMENTS PLANNING FREQUENCY

Weeks	Frequency (% of responses)
1	17.6
4	37.4
5	3.3
6	2.2
8	4.4
9	1.1
12	4.4
13	15.4
16	1.1
18	2.2
20	1.1
52	8.8

Mean	10.3 weeks
Median	4
Std. Dev.	13.8

be done each time production planning is done. Over half of the respondents indicated that they did resource planning either monthly or quarterly. This is consistent with the information provided by Berry, Vollmann and Whybark (1979).

When asked the title of the person who is responsible for doing resource requirements planning, 29 percent indicated that it was the materials manager who did this job. The next largest response was the ten percent who indicated that the manufacturing manager did resource planning. Other levels of the materials function such as director and vice president also were responsible for resource planning. In all, 44.6 percent of the respondents indicated that some level of materials was responsible for resource planning. There are little or no indications in the literature as to who should be doing resource planning, only that it should be done.

The final area explored in conjunction with the characteristics of production planning is the area of forecasting. There were numerous questions on forecasting.

The first of these dealt with the formality and regularity of forecasting for the facility in question or for the company in general. About 93 percent of the respondents for both the full sample and the PP sample reported on company forecasting (see Table 5-31). Regularity and formality were evaluated on a five point Likert scale. The mean score on company forecast regularity for the full sample was 4.3 with a median of five. Results for the reduced sample were similar with a mean of 4.4. and a median of five also. For formality, the mean was lower at 3.5 with a median of three. For the reduced sample, the mean

TABLE 5-31

FORECASTING INFORMATION

Company Forecast Frequency

.7%	4.7%	8.7%	20.1%	65.1%
not at all	irregularly	occasionally	frequently	regularly

Company Forecast Formality

3.6%	9.3%	28.6%	23.6%	34.3%
very informal no procedures		somewhat formal some procedures		very formal strict procedures

Facility Forecast Frequency

2.5%	5.9%	11.8%	19.3%	60.5%
not at all	irregularly	occasionally	frequently	regularly

Facility Forecast formality

5.7%	10.4%	27.4%	27.4%	29.2%
very informal no procedures		somewhat formal some procedures		very formal strict procedures

was 3.7 and the median was four. In both cases, it appears that forecasting is an important part of the planning for these companies.

For facilities, the response was similar. Regularity was reported to average 4.2 for the full sample and 4.3 for the reduced sample. The medians for the two samples were three and five respectively. Formality averaged 3.4 with a median of three for the full sample and averaged 3.6 with a median of four for the reduced sample. In both cases, the reduced sample showed better performance but in both the process was considered important to the respondents.

The overwhelming majority of the respondents indicated that forecasting was done by the marketing/sales groups. In fact for both the company and the facility, around 85 percent indicated that sales/marketing had that job. The second most popular group which forecasted was the materials group, a function which should NOT be doing it but is often forced to when no forecast is done by marketing/sales.

As discussed earlier, forecasting accuracy diminishes the further into the future that one attempts to forecast. For the full sample, the average forecast horizon for the company was 23 months with a median of 12 months and nearly 45 percent indicating that 12 months was the forecast horizon (see Table 5-32). Except for the mean of 23 months, results were identical for the reduced sample. Forecast horizon for the facilities averaged 22.8 months with a median and mode of 12 months also for both samples.

The respondents were also asked to report on the accuracy of their forecasting efforts but the responses were sparse and mostly estimated. Few (45 percent) indicated that they measured forecast accuracy for either sample. Those that estimated accuracy for

TABLE 5-32

FORECAST HORIZON

	Company	Facility
Mean	23.3 months	22.6 months
Median	12.0	12.0
Std. Dev.	20.0	20.0
Min	2	1
Max	100	81

TABLE 5-33

FORECAST USE

Used to Prepare	Full Sample	P/P Sample
Strategic Plan	54.8%	59.3%
Production Plan	61.4	92.7
Master Schedule	50.4	74.7
Other	4.9	5.3

families of products averaged 73 percent accuracy for the full sample and 79 percent for the reduced sample. Those that estimated forecast accuracy for end products averaged 73 percent accuracy for both samples. Those that forecasted spare parts or service parts estimated their accuracy at an average of 76.4 percent for the full sample and 77.1 percent for the reduced sample. For the full sample, less than 20 percent responded and for the reduced sample less than 23 percent responded. Even though the responses for the reduced sample were slightly better in a few cases, little or nothing can be made of this because of the rough nature of the estimates and infrequency of response. These measures of forecast accuracy were not used in the LISREL analysis.

Finally, respondents were asked where the forecast information was used. 54.8 percent of the full sample indicated that forecast information was used in preparation of the strategic plan (see Table 5-33). 59.3 percent of the reduced sample cited this use of forecasting. 61.4 percent indicated that the forecast was used in the preparation of the production plan for the full sample and this translated to a 92.7 percent response in the PP sample. 50.4 percent of the full sample used the forecast to prepare the master schedule while 74.7 percent of the PP sample used the forecast for the preparation of the master schedule. The differences between the two samples were deemed important. The use of the forecast seems to be more important for those with a more complete planning system.

In summary, the above discussions show that in many ways, the reduced sample has similar characteristics to the full sample especially as to the representiveness of the firms. There is also a clear indication that those firms with production plans represent better systems overall.

Pearson Correlation Analysis

A series of correlation analyses were undertaken to further explore the issue of bias. The focus was on overall company attributes such as sales, volumes, types of operation, and the number of parts, end items, salaried personnel and hourly personnel. These were correlated to the four success variables; MRP class, master schedule performance, inventory performance and customer delivery performance. Pearson correlations were calculated for both the full sample and the PP sample. In all cases, only those correlations which were significant at the .05 level at least, are reported.

There was little or no difference in the correlation information between those firms with a production plan and those without in all of the firm variables except that of batch volume.

Those companies which identified themselves as batch operations were somewhat correlated with success. In the full sample, the only correlation (at .17) with a significance at the .05 level or below was between batch volume and customer delivery indicating that as batch volumes increases so does customer delivery performance. More importantly, the reduced sample showed a correlation of .18 between batch volume and MRP class, .24 between batch volume and master schedule performance and .21 between batch volume and customer delivery performance. All of these are significant at the .05 level (see Table 5-34).

TABLE 5-34

PEARSON CORR. ANALYSIS

	MRP Class	MPS Perf.	Inv. Perf.	CD Perf.
Company Sales Full Sample				.15
Company Sales P/P Sample				.13*
Batch Volume Full Sample				.17
Batch Volume P/P Sample	.18	.24		.21
Repetitive Vol. Full Sample		.15	.16	.22
Repetitive Vol. P/P Sample		.16**	.17	.18
Continuous Vol. Full Sample		.35***		
Continuous Vol. P/P Sample		.29		

All coefficients are significant at the .05 level unless otherwise stated

* significant at the .08 level

** significant at the .07 level

*** significant at the .005 level

It is unclear why performance is not uniform with all levels of volume. It may be that those companies which have higher volumes get more serious about their systems and this results in better performance. It may also be that implementation of systems such as MRP do not commence until manufacturing volumes have risen and control is difficult. In other words, the reduced sample may include primarily those companies which are mature users of MRP. This may also explain why these correlations show up in the reduced sample and not in the full sample. Further, it must be remembered that many responded with multiple production types as noted earlier. If this is true, some respondent bias is introduced and results must be interpreted accordingly.

There were no significant correlations between parts end items, the number of salaried and hourly personnel and the success measures.

Except for batch volume issues which need to be noted in any final explanation, it appears from the above correlation analysis that little bias is introduced into the analysis by the use of the reduced sample only. Many of the variables will be discussed in greater detail in the LISREL analysis below.

Discriminant Analysis

The discriminant analysis was done to see if those firms with a production plan could be distinguished from those without based on overall system performance. This would constitute a test of the hypothesis that firms having a production plan outperform those without a plan.

Since one of the basic requirements of discriminant analysis is to assure that the populations are multivariate normal, the success measures were transformed to produce distributions which were more nearly normal. The discriminant statistic is fairly robust, so some departure from normality can be tolerated.

The program (SPSSX) first produced a table of univariate statistics of means and standard deviations for the two groups; those which have a production plan and those which do not.

Unfortunately, 61 cases were excluded from the analysis because one or more of the discriminating variables were missing from the case. This left 126 cases of companies with a production plan and 55 companies without.

The tables of univariate statistics (Table 5-35) shows that for each of the discriminating variables the means are smaller for those without a production plan than those with a production plan. This indicated reduced performance for those without a plan. In addition, the standard deviations are smaller for those with a plan than for those without indicating a somewhat tighter distribution.

Next a one way ANOVA was performed producing the associated F value to test equality of group means (Table 5-36). The table shows a high level of significance and high F values for master schedule performance, customer delivery performance and MRP class and a low F for inventory performance. Based on these tests, we can reject the hypothesis that the two group means are the same for the master schedule performance, MRP class and customer delivery performance variables. The implciations of the low F test on the customer delivery variable will be discussed in Chapter 6.

TABLE 5-35

UNIVARIATE STATISTICS

Group Means

Have PP	SQMPSPRF	MRPCLASS	SQINVPCT	SQCUSDEL
0	7589.04762	5.40476	7996.00794	8019.89484
1	6230.72727	3.90909	7553.38182	6622.06909
Total	7176.29834	4.95028	7861.50829	7595.13812

Group Standard Deviations

Have PP	SQMPSPRF	MPRCLASS	SQINVPCT	SQCUSDEL
0	1876.80983	2.40725	1619.60515	1706.54848
1	2114.49923	2.37481	1664.83973	2617.73971
Total	2044.48178	2.48836	1641.58223	2119.86376

TABLE 5-36

UNIVARIATE F-RATIO

Variable	F	Significance
SQMPSPRF	18.55	0.0001
MRPCLASS	14.90	0.0002
SQINVPCT	2.812	0.0953
SQCUSDEL	18.24	0.0001

TABLE 5-37

POOLED WITHIN-GROUPS CORRELATION MATRIX

	SQMPSPRF	MRPCLASS	SQINVPCT	SQCUSDEL
SQMPSPRF	1.00000			
MRPCLASS	0.41694	1.00000		
SQINVPCT	0.23143	0.21058	1.00000	
SQCUSDEL	0.66660	o.31188	0.21939	1.00000

Since interdependencies among the variables affect most multivariate analyses, a pooled within-groups correlation matrix of the predictor variables was generated to examine these relationships (Table 5-37). Customer delivery and master schedule performance have the highest correlation at .67. This is to be somewhat expected since, if one assumes that the master schedule is formulated to enable the company to meet customer commitments among other goals, good master schedule performance implies good customer delivery performance. Interpretation of results must take this relationship into account. The remaining correlations indicate much smaller relationships and little or no adjustment is needed in interpretation.

Next, the unstandardized discriminant function coefficients were calculated by forming a linear combination of the predictor variables. The weights which are calculated are estimated so that the "best" separation between the group occurs. The results of this analysis are shown in Table 5-38. This may be interpreted as the b's in a regression equation used to predict the value of the outcome variable, having a production plan. When multiplied by the value of the discriminating variables and summed, the discriminating function coefficients can be used to calculate the discriminant score for each case. Their standardized values can be found in Table 5-39.

Using the discriminant values calculated with the variables above, each case was evaluated and by its discriminant score, its group membership was predicted. The classification results are summarized in Table 5-40.

In analyzing these results it is important to consider that the prior probability for each group is .5 or that any case has a 50-50

TABLE 5-38

UNSTANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	Function 1
SQMPSPRF	.1675081D-03
MRPCLASS	.1902044
SQINVPCT	.3213312D-04
SQCUSDEL	.2231456D-03
(Constant)	-4.091089

TABLE 5-39

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	Function 1
SQMPSPRF	0.32690
MRPCLASS	0.45602
SQINVPCT	0.05249
SQCUSDEL	0.45189

TABLE 5-40

DISCRIMINANT ANALYSIS
CLASSIFICATION RESULTS

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 0	1
GROUP	0	126	87 69.0%	39 31.0%
GROUP	1	55	23 41.8%	32 58.2%

PERCENT OF "GROUPED" CASES CORRECTLY CLASSIFIED: 65.75%

chance to be assigned to one of the two groups. The results of the analysis were not clearly outstanding in that only 65.75 percent of the cases were classified correctly based on the calculation of the discriminant scores. This is however, much better than the random chance score of .5. Almost 70 percent of the classifications into the PP group were done correctly via the discriminant scores.

It appears from the analysis that several conclusions can be drawn. First, in general, the success variables can be used to discriminate between those companies which have a production plan and those which do not. Next, the best discriminating variables are those of master schedule performance, customer delivery and MRP class. Finally, the analysis appears to support the hypothesis that, on average, those companies which have a production plan outperform those which do not. The remaining tests that are performed are on those firms with a production plan.

Lisrel Analysis

Reviewing the model of Figure 5-1, the relationships under investigation are modeled using structural equation methodology. The conventions of structural equation methodology have been well defined in the social sciences by Bagozzi (1980) and Joreskog and Sorbom (1979, 1982). Circles represent latent or unmeasured variables. Squares represent measured variables. Greek letters represent parameters to be measured.

The hypotheses discussed earlier, are represented primarily by the γ (gamma) and β (beta) parameters.

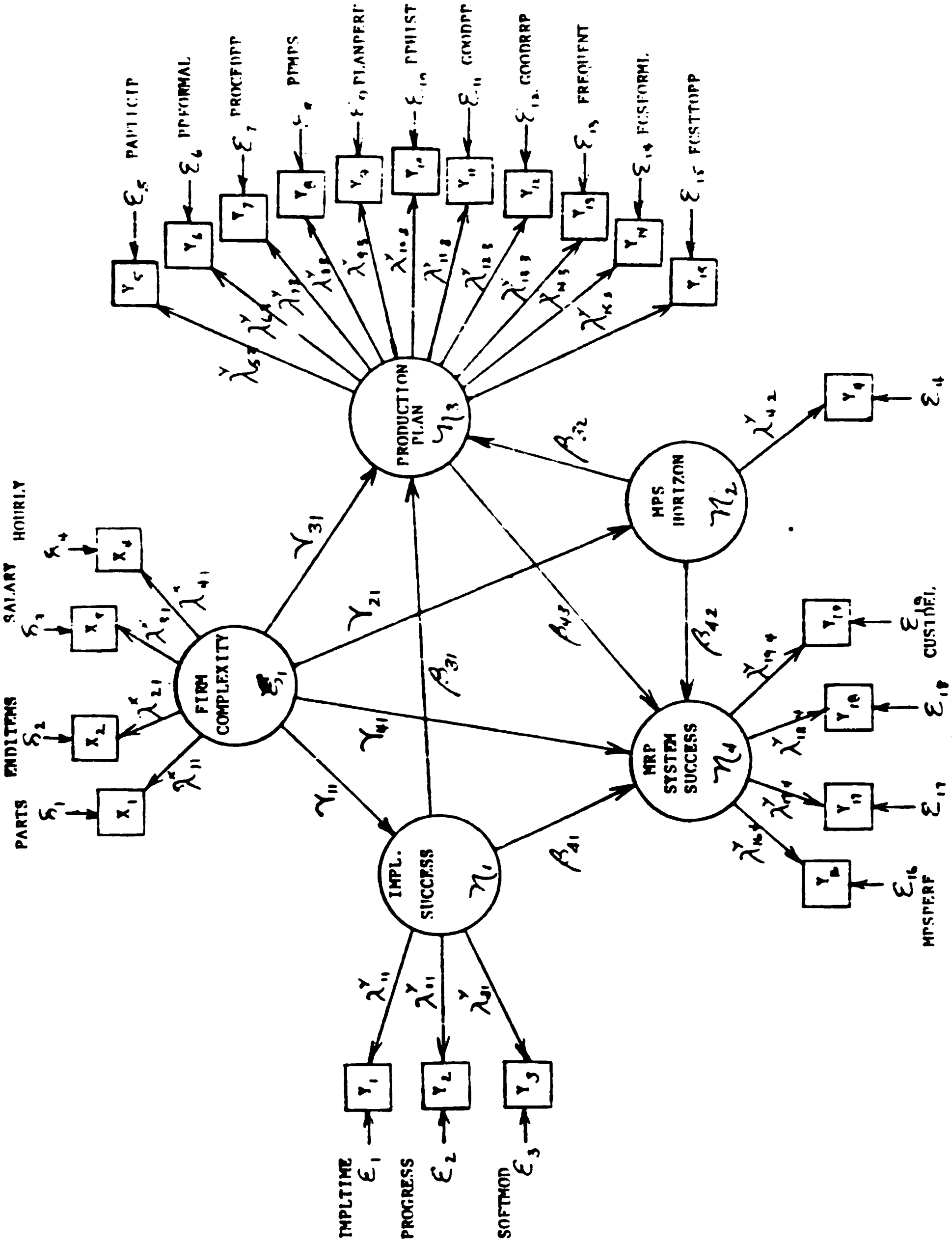

FIGURE 5-1

FIVE VARIABLE MODEL

Each γ parameter represents a hypothesized causal path between a latent independent variable ξ and a latent dependent variable η. Each β parameter represents a hypothesized causal path between two latent dependent variables with the hypothesized directionality of causation shown by the direction of the arrow between the latent variables.

To review these hypotheses, γ_{11} represents the hypothesis that firm complexity influences the success of implementation. The more complex the firm as measured by numbers of people and numbers of parts and product, the more difficult implementation success in the firm will be. Under this hypothesis, γ_{11} will be negative and significant.

γ_{21} represents the hypothesis that firm complexity affects the length of the master schedule horizon. As firms become more complex, there is a greater need to extend the planning horizon to account for longer lead times of the more complex product array. Under this hypothesis, γ_{21} will be positive and significant.

γ_{31} represents the hypothesis that firm complexity affects the existence and operation of the production plan. As firms become more complex, there is a greater need for longer term planning at a higher level in the planning hierarchy. These more complex firms are therefore more likely to have production plans and to have them more highly developed and formal. Under this hypothesis, γ_{31} will be positive and significant.

γ_{41} represents the hypothesis that firm complexity affects the overall success of the manufacturing control system as measured by master schedule performance, inventory performance, customer delivery performance and the state of the MRP system indicated by MRP class.

There are two possible scenarios here. More complex firms may have greater need for successful systems to manage their growth and ensure continued success. Under this hypothesis, γ_{41} would be positive and significant. On the other hand, firms with greater complexity may have greater difficulty achieving success as defined above. If this is the case, then γ_{41} would be negative and significant. These two views are not entirely exclusive. They can be reconciled by noting that while the need for better systems grows as the firm grows in complexity, implementation of such systems is often difficult and therefore, less complex firms may be more successful even with poorer systems. This is related to the discussion above on γ_{11}.

β_{31} represents the hypothesis that implementation success affects the existence of and performance of the production plan. The more successfully that the implementation has become, the closer it is to the MRP II model proposed by Wight (1980). In MRP II, the full system includes a production plan which provides input to the master schedule. While the standard MRP II software packages do not contain a production plan system as noted earlier, this higher level of planning is critical to the completion of the MRP II system and eventually to its success. This central thesis will be restated shortly. The hypothesis therefore predicts that β_{31} will be positive and significant.

β_{41} represents the hypothesis that implementation success affects success of the system directly in that the more fully developed and operational the system is, the more likely it is to be running successfully with good results (success) achieved. Under this hypothesis, β_{41} is hypothesized to be positive and significant.

β_{42} represents the hypothesis that the master schedule horizon affects the success of the system. If the master schedule horizon is not of sufficient length (at least as long as the total cumulative lead time of the products produced), master schedule performance will be difficult to achieve without seriously deteriorating the other measures of success. For example, it is possible to achieve master schedule performance under conditions of insufficient lead times by the use of excessive amounts of inventory at all stages of production. Under this hypothesis therefore, β_{42} is expected to be positive and significant.

β_{43} represents the hypothesis that the production plan influences the success of the firm's manufacturing control system. This is the central part of the study. Since all MRP system models call for a higher level of planning preceding the master schedule to attend to larger matters such as the setting of the level of production and the assurance of resource availability in the firm to facilitate the master schedule, there should be a strong relationship between the production plan and system performance. Therefore, β_{43} is expected to be positive and significant.

β_{32} represents the hypothesis that the master schedule horizon affects the production plan. Since the production plan is directly associated with the master schedule in the sense that one "drives" the other, the length of the master schedule horizon and indeed the existence of a well run master schedule can preclude the need for a production plan under certain conditions. These conditions relate to the length of the backlog vis-a-vis the length of the master schedule horizon as discussed earlier. Since, as will be described, the data on backlog was not collected, the direction of the relationship between the two variables is not clear. However, it will be assumed that the relationship is such that β_{32} will be positive and significant.

The variables which are measures of the latent independent and dependent constructs are shown as x's and y's respectively.

Reviewing these measures, firm complexity is represented by four variables. The first of these is the number of parts that the respondent firm currently deals with in its operations. In many cases, only active part numbers were reported. Since greater numbers of parts represents a larger task of control, this was felt to be a good representation of complexity. A second measure was the number of end items which are scheduled on a regular basis. It was felt that this is a better surrogate for complexity than the corresponding measure of sales in dollars. Clearly, the use of sales dollars has inherently built into it, sales margins which confuses the analysis in that large differences can be expected in margins across the sample and population. The next variable that was used to represent firm complexity was the number of salaried personnel at the implementing facility.

Since, systems like MRP are implemented primarily by salaried personnel and since the greater the number of salaried personnel, the greater the number of people who must be trained in system use, it was felt that larger numbers of salaried personnel added complexity to the management process as well as to the implementing process.

Finally, the number of hourly personnel was also felt to be a measure of firm complexity since it is this direct labor force that must be managed in the ordinary operation of the business and as a capacity/resource consideration in MRP. The above variables were designated x_1 to x_4, respectively. All these variables were measured on a ratio scale.

Implementation success was measured with three variables. The first of these was implementation time measured in months. In general, it is expected that the longer that the firm is at the implementation task, the more likely it is to succeed. This was demonstrated by Anderson et al. (1979).

The second of these measurements is progress which is measured by the number of system modules that were up and operating regularly. As implementation develops in a firm, more and more of the MRP system modules come on line and are operational. An additional sign of success in operationalizing the MRP system module is its regular use.

The last of the three measures of implementation success was the degree of software modification. Again according to the Anderson study, the more successful firms in implementation had modified standard software to a much greater degree than had those firms who had not progressed as far. This is mostly due to the fact that most MRP software packages which are purchased "off the shelf" must be customized to the needs of the specific firm using the software. The software is, of course, written in the most general terms to appeal to the largest possible spectrum of potential user. The above three variables were identified as y_1 to y_3, respectively. Implementation was measured in months on a ratio scale, progress was measured on an interval scale as was software modification.

The production plan was measured by eleven variables which correspond to the attributes of a production plan as discussed earlier.

The first of these was participation. Participation was measured by the number of different functions (e.g., sales, engineering, finance, etc.) which both participated in the plan's formulation and in its approval. Although information was collected on the titles of the participants, it was difficult to determine by title alone, the relative rank of the individual in the hierarchy and further, little could be said about comparisons between similar ranks in different organizations. Thus, it was felt that the best measure under the circumstances was that of number of participants and the departments they represented. Participation was measured on an interval scale.

Production plan formality was the second measure of the plan. In theory, the more formal the plan, the more likely it is to succeed. Formality was measured on a five point Likert ordinal scale.

The next measure chosen was production plan procedures. Again, it is believed that the more formal the plan procedures are and the more regularly the planning is done, the more likely the plan is to succeed. The procedures variable was measured on a five point Likert ordinal scale also.

The literature, as described above calls for the use of the production plan in preparation of the master schedule. This was included as a measure of the plan as a nominal variable.

Plan performance is a more direct measure of the success of the rest of the attributes of the plan, much the same way that MRP class is a measure of system success. It was measured as a ratio variable on a scale of 0 to 100 percent signifying the degree to which the plan was achieved from period to period.

Production plan history was used as a measure of planning by asking respondents to indicate how long such planning had been going on. Theoretically, the longer that planning had been done the more likely it was to be successful much the same way as longer implementation times implied more successful implementations.

The frequency of plan formulation and review was seen to be especially critical. Berry et al. (1979) in a limited sample, reported that most firms in the sample were using a monthly review period. Some, however, were employing a quarterly period. If monthly is taken as an optimal review period, then less frequently is seen to be worse. The variable was measured on a ratio scale as the absolute value of the difference in review period from a monthly period. This adapted for those respondents who reviewed the plan on a more frequent basis than monthly.

In the case of resource requirements planning (RRP), the measure was based around two significant points. First that RRP should be done in conjunction with production planning and second, that it should be done every time production planning is done. The measure was on a nominal scale where if neither condition was met, the variable was assigned a zero. If resource planning was done, the variable was assigned a five and if it was done each time production planning was done, it was assigned a value of ten.

Forecasting is an integral part of the production planning process as indicated above. Both the formality and the regularity/frequency of forecasting were used as variables to measure the attributes of production planning. Both were measured on a five point Likert like scale.

Finally, forecasting should be directly connected with production planning. Thus a nominal variable was introduced which was coded one if the forecast was used directly in the preparation of the production plan and zero if it was not. The above variables were numbered y_5 to y_{15} respectively.

Success of the system was measured with four variables. The first of these is master schedule performance. In successful systems, the master schedule is achieved to a high degree on a regular basis. The variable was taken as the average performance in percent of master schedule achieved over a three month period. Thus the scale used was a ratio scale.

A second measure of success was inventory performance. Master schedule performance can be achieved at the expense of excess inventories as noted earlier. The firm which sets and meets inventory goals on a regular basis to a high degree is seen as more successful than that which does not. This variable was also measured on a ratio scale from zero to 100 percent.

MRP class is a self evaluation of the state of achievement of the entire system and is based on the Oliver Wight A through D scale as discussed above. In this case the interval scale was divided into ten increments from D to A (low to high).

Finally, customer delivery is one of the most critical measures of any manufacturing control system and a high performance MRP system should assure a high performance in this area. The variable was measured on a zero to 100 percent ratio scale. These variables were marked y_{16} to y_{19}, respectively.

Returning to Figure 5-1, the λ_x's and λ_y's represent the factor loadings of the latent independent and dependent variables respectively. These values, when squared, represent the reliability of the measurements (Bagozzi, 1980), which indicates the degree of correspondence between measures and the concepts they intend to represent.

The δ's and the ε's represent the random error components of the measures. ζ's reflect error in the dependent variables due to factors omitted from the model of Figure 5-1, and ψ indicates correlations among these error terms.

Model Estimation and Evaluation

The model of Figure 5-1 was estimated using the LISREL VI program of Joreskog and Sorbom (1985). The program provides maximum likelihood estimates for all parameters to be estimated. In addition, it provides standard errors for all the estimates. Specific causal paths and factor loadings for each latent variable are tested and evaluated by T-values for each of the parameters and also for the error terms.

The model provides a chi-squared statistic for overall fit but it must be used with caution. The chi-square is very sensitive to departures from normality in the data provided and also to the size of the sample. It is best used as a comparison statistic for evaluating two competing model hypotheses.

Other indications of fit provided in LISREL VI are squared multiple correlations, coefficients of determination and correlations of the parameter estimates.

If the model of Figure 5-1 is rejected according to the goodness-of-fit measures, at least one or more of the elements of the hypothesized causal structure is inconsistent with the observations. These and other issues have been discussed in greater detail in Chapter 4, Research Methodology.

Table 5-41 shows the parameter estimates provided by LISREL VI. Uniform scaling was assured by setting at least one variable in each measurement group equal to one. In this case, all other variables are given in terms of the variable set to one.

Initially, for Eta 1 IMPLTIME was set to one; for Eta 2 MSHORIZN was set to one; for Eta 3 PARTICIP was set to zero and for Eta 4 MPSPERF was set to one. This then set the scaling of all remaining parameters to be estimated.

The maximum likelihood LISREL estimates resulting from this scheme are shown in Table 5-41. A quick review of these results indicates that some of the parameter estimates are very small. Of particular concern is the magnitude of the gamma estimates, with the exception of γ_{41} all of the estimates are very small. To further explore this issue, T-values for these estimates were assessed. In all cases, the estimates were not significant at the .05 level. Further, in examining the total effects computed for the model (see Table 5-42), it is clear that the total effects of ksi, (firm complexity, on the endogenous variables eta was very small in relation to those of the eta variables among themselves.

Further, the determinant of the input correlation matrix to LISREL VI was given as .000743 which is exceedingly small in relation to the diagonal elements of the matrix. This determinant is a measure of the ill-conditioning of the matrix (LISREL manual, p. III.8). This indicates that there are one or more nearly perfect linear

TABLE 5-41

LISREL ESTIMATES-FIVE VARIABLE MODEL

LAMBDA Y

	ETA 1	ETA 2	ETA 3	ETA 4
IMPLTIME	1.000	0.0	0.0	0.0
PROGRESS	1.856	0.0	0.0	0.0
SOFTMOD	1.448	0.0	0.0	0.0
MSHOFIZN	0.0	1.000	0.0	0.0
PARTICIP	0.0	0.0	1.000	0.0
PPFORMAL	0.0	0.0	2.294	0.0
PROCEDPP	0.0	0.0	2.610	0.0
PPMPS	0.0	0.0	0.377	0.0
PLANPERF	0.0	0.0	1.335	0.0
PPHIST	0.0	0.0	0.848	0.0
GOODPP	0.0	0.0	0.101	0.0
GOODRRP	0.0	0.0	1.162	0.0
FREQUENT	0.0	0.0	2.007	0.0
FCSFORML	0.0	0.0	3.100	0.0
FCSTTOPP	0.0	0.0	0.210	0.0
MPSPERF	0.0	0.0	0.0	1.000
MRPCLASS	0.0	0.0	0.0	0.823
INVPCT	0.0	0.0	0.0	0.442
CUSTDEL	0.0	0.0	0.0	0.577

LAMBDA X

	KSI 1
PARTS	0.829
ENDITEMS	0.525
SALARY	0.921
HOURLY	1.009

BETA

	ETA 1	ETA 2	ETA 3	ETA 4
ETA 1	0.0	0.0	0.0	0.0
ETA 2	0.215	0.0	0.0	0.0
ETA 3	0.365	0.005	0.0	0.0
ETA 4	0.656	0.099	1.401	0.0

GAMMA

	KSI 1
ETA 1	0.054
ETA 2	0.024
ETA 3	0.054
ETA 4	-0.214

TABLE 5-42

LISREL ESTIMATES-FIVE VARIABLE MODEL

TOTAL EFFECTS

TOTAL EFFECTS OF KSI ON ETA

	KSI 1
ETA 1	0.054
ETA 2	0.044
ETA 3	0.089
ETA 4	-0.020

TOTAL EFFECTS OF KSI ON Y

	KSI 1
IMPLTIME	0.054
PROGRESS	0.174
SOFTMOD	0.136
MSHORIZN	0.044
PARTICIP	0.089
PPFORMAL	0.204
PROCEDPP	0.232
PPMPS	0.034
PLANPERF	0.119
PPHIST	0.075
GOODPP	0.009
GOODRRP	0.103
FREQUENT	0.178
FCSFORML	0.275
FCSTTCPP	0.019
MPSPERF	-0.020
MRPCLASS	-0.017
INVPCT	-0.009
CUSTDEL	-0.020

TOTAL EFFECTS OF ETA ON ETA

	ETA 1	ETA 2	ETA 3	ETA 4
ETA 1	0.0	0.0	0.0	0.0
ETA 2	0.215	0.0	0.0	0.0
ETA 3	0.366	0.005	-0.000	0.0
ETA 4	1.230	0.106	1.401	0.0

relationships among the observed variables and it is best to delete one or more variables.

Given the small values of gamma their non-significance and the problems of ill-conditioning, it was decided to eliminate the entire firm complexity variable from the model even though the factor loadings determined in Table 5-41 were quite good and were also found to be significant. That is, the factor loadings of PARTS, ENDITEMS, SALARY and HOURLY which ranged from .525 to 1.009 were all found to be significant at the .05 level with T values from 6.8 to 14. This indicated that these measures of the construct accounted for the overall variance very well. Only the relationships of the construct to the other variables and constructs in the model was poor. Interestingly enough, the sign of γ_{41} is negative which seems to support the hypothesis that firm complexity adversely affects the success of the system. Since, however, the value is non-significant at the .05 level such conclusions may not be in order.

After elimination of the firm complexity variables the model appears as in Figure 5-2. Implementation success and master schedule horizon are now exogenous to the system as determined by the hypothesized causal effects paths.

At the outset of this model analysis, PARTICIP was set to one arbitrarily as in the previous case. As a result, the parameter estimates ranged from .193 to 3.328 (see Table 5-43).

To insure scaling that was easier to interpret, scaling was changed to set FCSFORML (the largest parameter estimate) to one. Results of that scheme can be found in Table 5-44. This assured that the scale of parameter estimates ranged from zero to one.

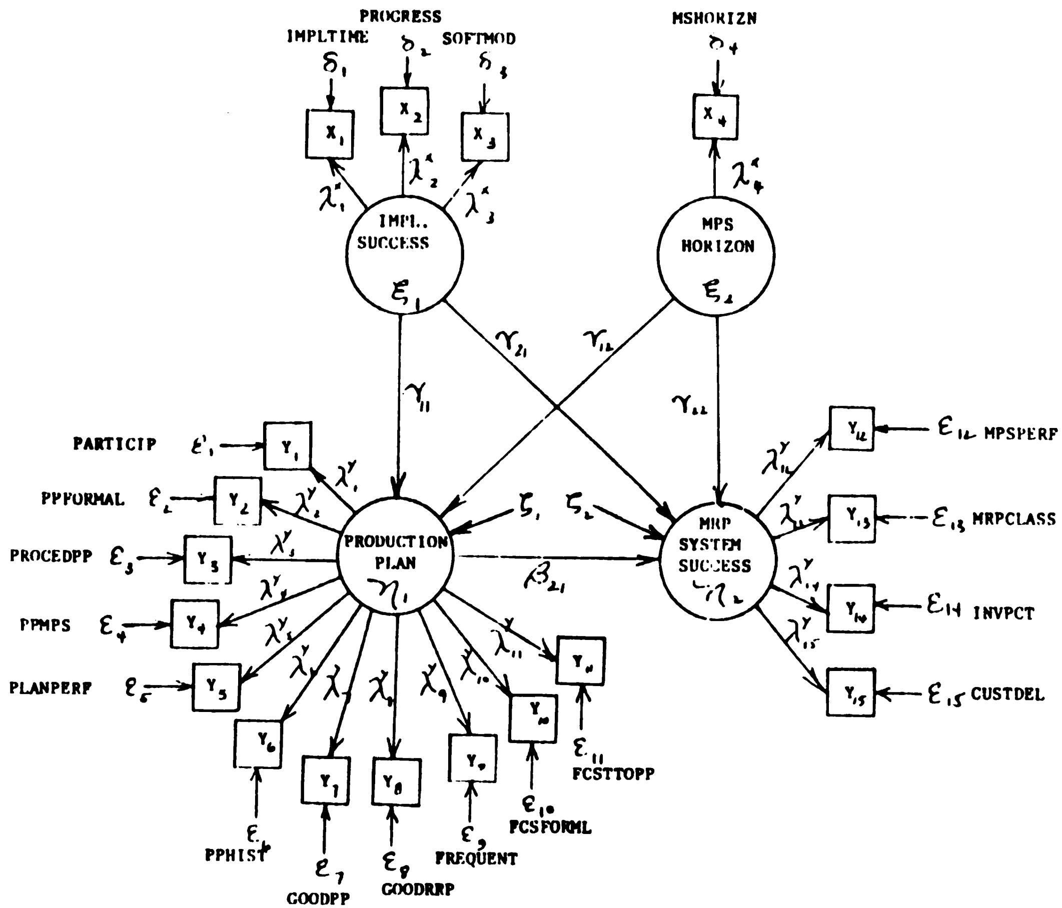

FIGURE 5-2

FOUR VARIABLE MODEL

TABLE 5-43

LISREL ESTIMATES
PARTICIPATION SET TO 1

Lambda Y

	ETA 1	ETA 2
PARTICIP	1.000	0.0
PPFORMAL	2.148	0.0
PROCEDPP	2.352	0.0
PPMPS	0.439	0.0
PLANPERF	1.236	0.0
PPHIST	0.666	0.0
GOODPP	0.213	0.0
GOODRRP	1.066	0.0
FREQUENT	2.194	0.0
FCSFORML	3.328	0.0
FCSTTOPP	0.193	0.0
MPSPERF	0.0	1.000
MRPCLASS	0.0	0.765
INVPCT	0.0	0.449
CUS[illegible]	0.[illegible]	0.962

TABLE 5-44

LISREL ESTIMATES

LAMBDA Y

	ETA 1	ETA 2
PARTICIP	0.297	0.0
PPFORMAL	0.626	C.0
PROCEDPP	0.676	0.0
PPMPS	0.123	0.0
PLANPERF	0.074	0.565
PPHIST	0.192	0.0
GOODPP	0.081	0.0
GOCDRRP	0.297	0.0
FREQUENT	0.667	0.0
FCSFORML	1.000	0.0
FCSTTOPP	0.047	0.0
MPSPERF	0.0	1.000
MRPCLASS	0.0	0.776
INVPCT	0.0	0.443
CUSTDEL	0.0	0.953

LAMBDA X

	KSI 1	KSI 2
IMPLTIME	0.509	0.0
PROGRESS	0.594	0.0
SOFTMOD	0.449	0.0
MSHORIZN	0.0	1.000

BETA

	ETA 1	ETA 2
ETA 1	0.0	0.0
ETA 2	0.358	0.0

GAMMA

	KSI 1	KSI 2
ETA 1	0.353	C.010
ETA 2	0.147	0.079

PHI

	KSI 1	KSI 2
KSI 1	1.000	
KSI 2	0.098	1.000

Additionally, it was then possible to evaluate the strength of the variable previously set to one.

Table 5-44 shows that the strongest relationships between the variables designed to represent the production plan are FCSFORML (the formality of forecasting), PROCEDPP (production plan procedures), FREQUEST (the frequency and regularity of forecasting) and PPFORMAL (the formality of the production planning process).

These results agree with those found in the previous model (Figure 5-1) evaluated above. The model is robust in this regard. These four factor loadings were significant at the .05 level (see Table 5-45).

Two other factors were significant at the .05 level. These were PARTICIP (the level of participation in the planning process) and GOODRRP (resource requirements planning done in conjunction with production planning discussed above).

The strength of these relationships was less than that of the above mentioned four variables. The remaining variables had much smaller magnitudes and were not significant at the .05 level. Thus, six of the variables combine to represent the majority of the variance of the measures taken together.

Initially, the analysis showed PLANPERF (the performance of the production plan) as significant at the .05 level and with a parameter estimate just below that of PPFORMAL. However, the LISREL analysis identified this variable as one with a high modification index.

Modification indices indicate the expected decrease in chi-square if a single constraint is relaxed and all the estimated parameters are held fixed at their estimated value (LISREL VI manual,

TABLE 5-45

T-VALUES

LAMBDA Y

	ETA 1	ETA 2
PARTICIP	3.054	0.0
PPFORMAL	6.489	0.0
PRCCEDPP	6.959	0.0
PPMPS	1.264	0.0
PLANPERF	0.645	3.779
PPHIST	1.967	0.0
GCCDPP	0.833	0.0
GOCDRRP	3.057	0.0
FREQUENT	6.903	0.0
FCSFORML	0.0	0.0
FCSTTOPP	0.485	0.0
MPSPERF	0.0	0.0
MRPCLASS	0.0	6.163
INVPCT	0.0	3.670
CUSTDEL	0.0	7.077

LAMBDA X

	KSI 1	KSI 2
IMPLTIME	0.0	0.0
PRCGRESS	5.329	0.0
SOFTMCD	4.290	0.0
MSHORIZN	0.0	0.0

BETA

	ETA 1	ETA 2
ETA 1	0.0	0.0
ETA 2	3.468	0.0

GAMMA

	KSI 1	KSI 2
ETA 1	3.826	0.134
ETA 2	1.433	1.275

PHI

	KSI 1	KSI 2
KSI 1	0.0	
KSI 2	0.915	0.0

p. I.42). In other words, if the fixed parameter with the highest modification index is relaxed, the fit of the model as measured by the reduction of the chi-square will improve by at least the amount of the modifcation index. However, parameters cannot be relaxed arbitrarily. Only those parameters which make sense from a substantive point of view and can be supported and interpreted theoretically may be relaxed.

Accordingly, a modification index of 14.67 for the PLANPERF variable (the average percent of actual performance to plan over the previous three planning periods) indicated that this variable should be freed to load on the success variable.

Theoretical justification can be made for this action. Except for the plan performance variable, all the production plan variables are connected with the formulation or operation of the production plan. Plan performance is more a measure of the outcome of those activities. Indeed, it may be interpreted as a success variable in much the same way as master schedule performance is used to measure success of the MRP system. Once this variable was allowed to be freed to load on Eta 2, success, its parameter value became significant at the .05 level loading on the MRP system success construct and was no longer a significant loading on the production plan construct.

All of the parameter estimates for success η_2, were found to be significant at the .05 level. MPSPERF (the average percent achieved of the master schedule over the previous three planning periods) and CUSTDEL (the percent of on time deliveries to customer promise) had the highest parameter estimates. MRPCLASS (a self evaluation of the class of the MRP system using the Oliver Wight model) was also an indicator but with a smaller magnitude. This was followed in order of importance by PLANPERF (discussed above) and INVPCT (the degree to which inventory goals were met).

Only the parameters associated with implementation success of the two exogenous latent constructs, implementation success and master schedule horizon were estimated by the program. This was because the master schedule horizon construct was measured by only one variable (MSHORIZN) which was set to one for identification and scaling purposes (see above). When a single indicator is used to represent a construct, the measurement error is assumed to be zero (Dillon and Goldstein, 1984) and no comparable scaling for associated variables measuring that construct is possible.

The model would clearly have benefited greatly if other measures of this latent variable (master schedule horizon) were used. Since, however, no data was collected on backlog, only one measure was possible. Future studies would be improved by use of additional measures.

IMPLTIME (the length of time in months of implementation), PROGRESS (the number of software modules up and operational) and SOFTMOD (the degree to which the MRP software had been modified) all proved roughly equal factor loadings according to the parameter estimates. In addition, all were significant at the .05 level.

Parameter estimates of Beta and Gamma were also estimated by the program. These estimates and their magnitude are affected by the choice of the measurement variables for scaling purposes. The standard errors of the estimates are correspondingly altered to reflect the changes in scaling so that the subsequent T values computed are consistent. In this case, β_{21}, the effect of the production plan on system success, was significant at the .05 level. However, γ_{11}, the effect of implementation success on the production plan was the only gamma variable that was significant at the .05 level. This means that the parameter value of the effect of implementation success on system success was not significant at the .05 level. The value of this parameter is a little less than 40 percent of the value of the parameter which shows the direct effect of the implementation success on the production plan. This is somewhat surprising since it indicates that implementation success affects MRP system success more strongly through the production plan than directly. The implication is that system success can only be maximized through the use of a production plan. This will be discussed in detail in Chapter 6.

Further information may be gathered by consideration of total effects calculated in the model. A summary of these effects can be found in Table 5-46. Total effects are made up of direct effects and indirect effects. Direct effects are those relationships between two variables directly without intervening variables.

The total effect of ETa 1 on Eta 2 is simply the estimated parameter β_{21} since there are no intervening variables. The total effect of Ksi 1 on Eta 2, however is made up of the direct effect of Ksi 1 on Eta 2 and the indirect effect of Ksi 1 on Eta 2 through Eta 1. The total effect of Ksi 2, master schedule horizon, on the production plan is very small in relation to the effects of Ksi 1, implementation success. The same is true of the effect of master schedule horizon on system success but its effect is larger than that of Ksi 2 on Eta 1.

TABLE 5-46

TOTAL EFFECTS

TOTAL EFFECTS OF KSI ON ETA

	KSI 1	KSI 2
ETA 1	0.353	0.010
ETA 2	0.287	0.082

TOTAL EFFECTS OF KSI ON Y

	KSI 1	KSI 2
PARTICIP	0.117	0.003
PPFORMAL	0.246	0.006
PRCCEDPP	0.266	0.007
PPMPS	0.048	0.001
PLANPERF	0.191	0.047
PPHIST	0.075	0.002
GCCDPP	0.032	0.001
GOCDRRP	0.117	0.003
FREQUENT	0.262	0.007
FCSFORML	0.393	0.010
FCSTTCPP	0.019	0.000
MPSPERF	0.287	0.082
MRPCLASS	0.223	0.064
INVPCT	0.127	0.036
CUSTDEL	0.274	0.078

TOTAL EFFECTS OF ETA ON ETA

	ETA 1	ETA 2
ETA 1	0.0	0.0
ETA 2	0.358	0.0

The total effects of Ksi 1, implementation success, on the measured variables shows a strong relationship to both the measured variables connected with the production plan and with those of system success. This is to be expected when the strong relationship between the production plan and system success is considered. Likewise, the total effects of Ksi 2 (master schedule horizon) on the same measured variables is very weak in relation to that of Ksi 1 (implementation success).

Interpretation of these relationships and those of the parameter estimates are given below and in Chapter 6.

Table 5-47 describes the total effects of the endogenous variables on the measured variables and in the case of the variables associated with each eta, are identical to the ML estimates as is to be expected.

Additional information provided in this table is the total effect of Eta 1, the production plan, on the measures of system success. Comparison of the magnitude of these later effects can be made to those of the production plan measures noting that the smaller magnitude is due to the fact that the effects are indirect.

Table 5-48 shows a standardized solution and can be treated as a series of beta weights found in regression equation analysis. Comparison of the information in Table 5-48 to that of the above tables shows no significant additional information. The relative strengths of the relationships remain approximately the same.

TABLE 5-47

TOTAL EFFECTS OF ETA ON Y

	ETA 1	ETA 2
PARTICIP	0.297	0.0
PPFORMAL	0.626	0.0
PRCCEDPP	0.676	0.0
PPMPS	0.123	0.0
PLANPERF	0.276	0.565
PPHIST	0.192	0.0
GOCDPP	0.081	0.0
GOCDRRP	0.297	0.0
FREQUENT	0.667	0.0
FCSFCRML	1.000	0.0
FCSTTOPP	0.047	0.0
MPSPERF	0.358	1.000
MRPCLASS	0.278	0.776
INVPCT	0.159	0.443
CUSTDEL	0.341	0.953

TABLE 5-48

STANDARDIZED SOLUTION

LAMBDA Y

	ETA 1	ETA 2
PARTICIP	0.259	0.0
PPFORMAL	0.547	0.0
PROCEDPP	0.591	0.0
PPMPS	0.108	0.0
PLANPERF	0.065	0.422
PPHIST	0.168	0.0
GOODPP	0.071	0.0
GOODRRP	0.260	0.0
FREQUENT	0.583	0.0
FCSFORML	0.874	0.0
FCSTTOPP	0.041	0.0
MPSPERF	0.0	0.746
MRPCLASS	0.0	0.579
INVPCT	0.0	0.331
CUSTDEL	0.0	0.711

LAMBDA X

	KSI 1	KSI 2
IMPLTIME	0.509	0.0
PROGRESS	0.594	0.0
SOFTMOD	0.449	0.0
MSHORIZN	0.0	1.000

BETA

	ETA 1	ETA 2
ETA 1	0.0	0.0
ETA 2	0.419	0.0

GAMMA

	KSI 1	KSI 2
ETA 1	0.450	0.012
ETA 2	0.196	0.105

PHI

	KSI 1	KSI 2
KSI 1	1.000	
KSI 2	0.098	1.000

PSI

ETA 1	ETA 2
0.797	0.692

Fit of the Model

As indicated earlier, fit of the model must be judged from a variety of information. Standard errors, squared multiple correlations, coefficients of determination, correlations of parameter estimates, chi-squared tests, Q-plot of residuals, magnitudes of the error terms and goodness of fit indices are all indicators of the fit of the model.

In the case of the parameter estimates, poor fits are indicated by negative variances, correlations which are larger than one in magnitude and covariance or correlation matrices which are not positive definite (LISREL VI manual, p. I.36). Such is not the case of the model under consideration (see Tables 5-46 and 5-47).

Other indications of poor fits are large standard errors and parameter estimates that are highly correlated. In this latter case, consideration of Table 5-49 shows a small number of correlations (18 of 6050) which can be considered large (a correlation was considered large when it exceeded plus or minus .3 in magnitude. This was an arbitrary decision).

All of the matrices were positive definite and there were no negative variances. Consideration of the Q-plot (Figure 5-3) however, shows a model of only fair fit. In general, consideration of the normalized residuals (Table 5-50) where each normalized residual is approximately a standard normal variable, is useful in detecting poor fits. Any normalized residuals greater than two in magnitude is an indication of poor fit (LISREL VI manual, p. III.15). Inspection of Table 5-50 will show there are 13 such values greater than two. This is an indicator of a fit poorer than is desired.

TABLE 5-49

CORRELATIONS OF ESTIMATES

	LY 11 1	LY 13 2	LY 14 2	LY 15 2	LX 2 1	LX 3 1	BE 2 1	GA 1 1	GA 1 2	GA 2 1
LY 11 1	1.000									
LY 13 2	-0.000	1.000								
LY 14 2	-0.000	0.207	1.000							
LY 15 2	-0.000	0.418	0.248	1.000						
LX 2 1	-0.000	-0.000	-0.000	-0.000	1.000					
LX 3 1	0.000	-0.000	-0.000	-0.000	-0.077	1.000				
BE 2 1	0.011	-0.178	-0.103	-0.221	0.068	0.018	1.000			
GA 1 1	-0.007	-0.000	-0.000	-0.000	-0.076	0.012	-0.142	1.000		
GA 1 2	-0.000	-0.000	-0.000	-0.000	0.038	0.010	0.018	-0.145	1.000	
GA 2 1	-0.002	-0.075	-0.043	-0.093	-0.056	-0.003	-0.542	0.026	-0.009	1.000
GA 2 2	-0.000	-0.066	-0.038	-0.083	0.016	0.004	0.043	-0.001	-0.006	-0.109
PH 2 1	0.000	-0.000	0.000	-0.000	-0.018	0.003	-0.008	0.046	-0.228	0.020
PS 1 1	-0.026	0.000	0.000	0.000	0.045	0.028	-0.139	-0.251	0.051	0.036
PS 2 2	-0.001	-0.473	-0.277	-0.565	0.018	0.005	0.138	0.006	0.001	-0.035
TE 1 1	-0.001	0.000	0.000	0.000	-0.000	-0.000	-0.005	0.003	0.000	0.001
TE 2 2	-0.004	0.000	0.000	0.000	-0.000	-0.000	-0.032	0.019	0.001	0.006
TE 3 3	-0.005	0.000	0.000	0.000	-0.000	-0.000	-0.041	0.025	0.001	0.008
TE 4 4	-0.000	0.000	0.000	0.000	-0.000	-0.000	-0.001	0.000	0.000	0.000
TE 5 5	-0.000	-0.011	-0.007	-0.006	-0.000	-0.000	0.001	0.001	0.000	0.016
TE 6 6	-0.000	0.002	0.000	0.000	-0.000	-0.000	-0.002	0.001	0.000	0.000
TE 7 7	-0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000
TE 8 8	-0.001	0.000	0.000	0.000	-0.000	-0.000	-0.005	0.003	0.000	0.001
TE 9 9	-0.005	0.002	0.000	0.000	-0.000	-0.000	-0.039	0.024	0.001	0.007
TE 10 10	0.028	-0.002	-0.000	-0.000	0.000	0.000	0.245	-0.082	-0.003	-0.069
TE 11 11	-0.010	0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000
TE 12 12	-0.000	0.337	0.192	0.439	-0.000	-0.000	-0.115	-0.000	-0.000	-0.051
TE 13 13	-0.000	-0.257	-0.015	-0.013	0.000	-0.000	0.028	-0.000	-0.000	0.011
TE 14 14	-0.000	-0.004	-0.125	-0.003	-0.000	-0.000	0.006	-0.000	-0.000	0.002
TE 15 15	-0.000	-0.059	-0.041	-0.411	0.000	0.000	0.079	-0.000	-0.006	0.031
TD 1 1	0.000	0.000	0.000	-0.000	0.131	0.057	-0.011	0.052	-0.042	0.024
TD 2 2	0.000	0.000	0.000	0.000	-0.618	0.156	-0.074	0.148	-0.009	0.085
TD 3 3	-0.000	0.000	0.000	0.000	0.129	-0.416	-0.016	0.032		0.018

	GA 2 2	PH 2 1	PS 1 1	PS 2 2	TE 1 1	TE 2 2	TE 3 3	TE 4 4	TE 5 5	TE 6 6
GA 2 2	1.000									
PH 2 1	-0.127	1.000								
PS 1 1	0.003	-0.011	1.000							
PS 2 2	0.080	-0.002	0.021	1.000						
TE 1 1	0.000	-0.000	0.011	0.001	1.000					
TE 2 2	0.000	-0.000	0.072	0.004	0.002	1.000				
TE 3 3	0.000	-0.000	0.092	0.005	0.002	0.016	1.000			
TE 4 4	0.000	-0.000	0.002	0.000	0.000	0.000	0.000	1.000		
TE 5 5	0.005	-0.000	0.000	0.027	0.000	0.000	0.000	0.000	1.000	
TE 6 6	0.000	-0.000	0.005	0.000	0.000	0.001	0.001	0.000	0.000	1.000
TE 7 7	0.000	-0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TE 8 8	0.000	-0.000	0.011	0.001	0.000	0.002	0.002	0.000	0.000	0.000
TE 9 9	0.000	-0.000	0.088	0.004	0.002	0.015	0.019	0.000	0.000	0.001
TE 10 10	-0.003	0.000	-0.462	-0.042	-0.022	-0.142	-0.187	-0.004	-0.001	-0.007
TE 11 11	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TE 12 12	-0.045	-0.000	0.000	-0.417	0.000	0.000	0.000	0.000	-0.019	0.000
TE 13 13	0.010	-0.000	0.000	0.040	0.000	0.000	0.000	0.000	-0.009	0.000
TE 14 14	0.002	-0.000	0.000	0.008	0.002	0.000	0.000	0.000	-0.002	0.000
TE 15 15	0.027	0.000	0.000	0.111	0.000	0.000	0.000	0.000	-0.024	0.000
TD 1 1	-0.003	0.012	-0.015	-0.003	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
TD 2 2	-0.018	0.015	-0.104	-0.017	0.000	-0.000	-0.000	-0.000	0.000	-0.000
TD 3 3	-0.004	0.008	-0.022	-0.004	0.000	0.000	0.000	0.000	0.000	0.000

CORRELATIONS OF ESTIMATES

	TE 7 7	TE 8 8	TE 9 9	TE 10 10	TE 11 11	TE 12 12	TE 13 13	TE 14 14	TE 15 15	TD 1 1
TE 7 7	1.000									
TE 8 8	0.000	1.000								
TE 9 9	0.000	0.002	1.000							
TE 10 10	-0.002	-0.022	-0.171	1.000						
TE 11 11	0.000	0.000	0.000	-0.001	1.000					
TE 12 12	0.000	0.000	0.000	-0.000	0.000	1.000				
TE 13 13	0.000	0.000	0.000	-0.000	0.000	-0.079	1.000			
TE 14 14	0.000	0.000	0.000	-0.000	0.000	-0.017	-0.004	1.000		
TE 15 15	0.000	0.000	0.000	-0.000	0.000	-0.222	-0.049	-0.010	1.000	
TD 1 1	-0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	1.000
TD 2 2	-0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.097
TD 3 3	0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.071

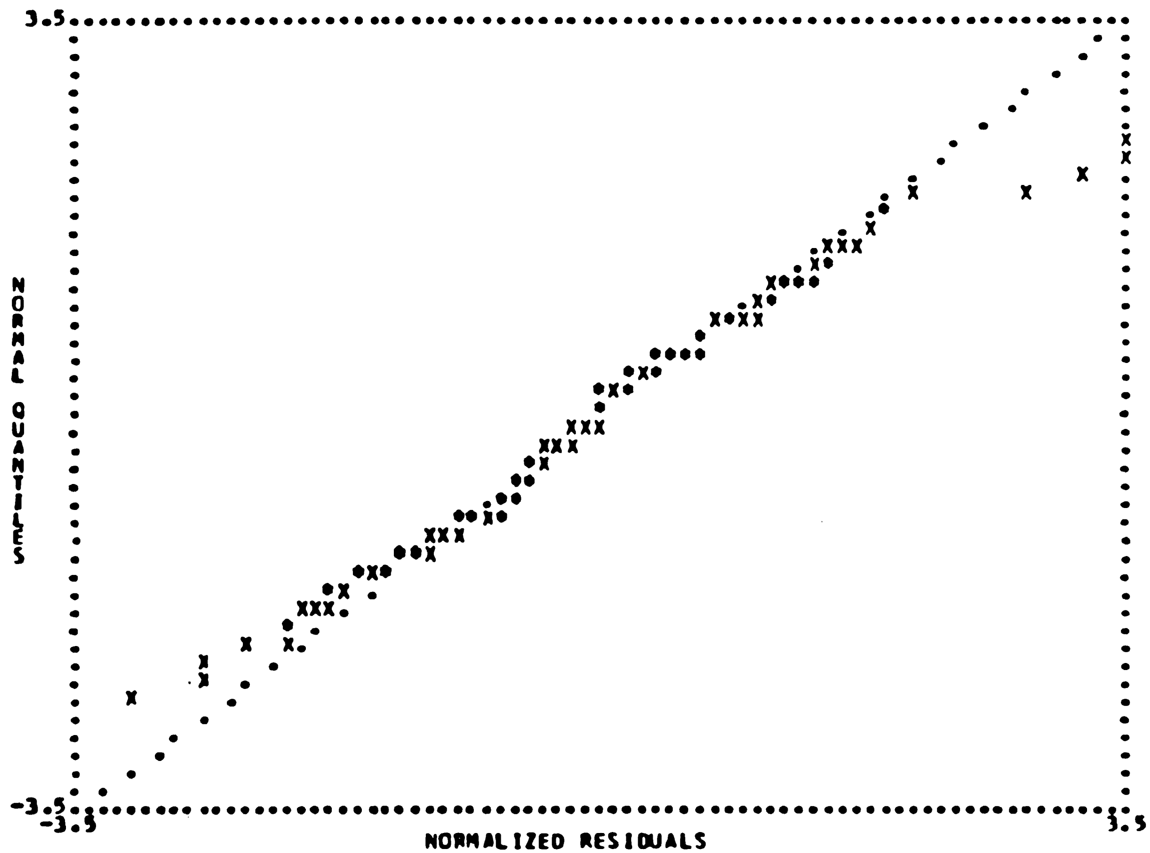

FIGURE 5-3

Q PLOT OF NORMALIZED RESIDUALS

TABLE 5-50

NORMALIZED RESIDUALS

	PARTICIP	PPFORMAL	PROCEDPP	PPMPS	PLANPERF	PPHIST	GOODPP	GOODRRP	FREQUENT	FCSFORML
PARTICIP	-0.007									
PPFORMAL	-0.865	-0.031								
PROCEDPP	-0.477	3.203	-0.036							
PPMPS	0.680	0.143	0.692	-0.001						
PLANPERF	-0.662	-0.504	0.756	0.670	-0.019					
PPHIST	-0.707	-0.152	1.124	-1.793	0.318	-0.003				
GOODPP	0.925	-0.938	-1.555	-3.153	-2.641	1.033	-0.001			
GOODRRP	0.442	0.753	0.187	0.612	1.170	-0.564	-0.335	-0.007		
FREQUENT	-0.374	-0.635	-1.936	0.354	-1.816	-0.393	-0.347	0.445	-0.035	
FCSFORML	0.240	-0.454	-0.384	-0.285	0.231	-0.177	0.813	-0.856	0.657	-0.078
FCSTTOPP	3.530	1.523	-0.045	0.691	0.241	-2.379	0.316	1.168	-0.938	-0.584
MPSPERF	1.779	-0.923	0.975	-0.042	0.051	0.187	-0.374	1.365	-1.195	-0.609
MRPCLASS	0.443	-0.664	1.169	0.220	0.680	-0.989	0.014	1.544	0.459	1.475
INVPCT	0.026	1.131	1.415	-1.720	0.124	1.940	-0.595	0.680	0.659	1.714
CUSTDEL	-0.614	-1.647	-0.005	-0.549	-0.380	1.134	0.653	1.540	-1.827	-0.705
IMPLTIME	-2.017	-1.286	-1.335	-0.208	-1.463	0.104	-0.946	0.261	-1.229	-2.121
PROGRESS	1.274	-1.070	-0.703	1.546	0.226	-0.090	0.373	1.420	1.424	0.871
SOFTMOD	-1.564	-1.092	-0.605	-1.370	0.714	2.048	-0.808	1.589	0.801	0.419
MSHORIZN	-0.379	-1.356	1.244	-0.165	-2.093	0.661	1.103	0.230	1.780	-0.484

NORMALIZED RESIDUALS

	FCSTTOPP	MPSPERF	MRPCLASS	INVPCT	CUSTDEL	IMPLTIME	PROGRESS	SOFTMOD	MSHORIZN
FCSTTOPP	-0.000								
MPSPERF	0.633	-0.044							
MRPCLASS	2.800	-0.684	-0.027						
INVPCT	-0.907	-0.205	-0.507	-0.009					
CUSTDEL	0.170	0.607	-0.378	-0.436	-0.040				
IMPLTIME	-0.543	-2.656	-0.030	-0.992	-2.122	-0.895			
PROGRESS	1.817	-0.437	5.428	-0.195	0.690	-1.428	-0.175		
SOFTMOD	-0.195	-1.144	0.188	1.311	-0.510	0.202	-0.792	-0.101	
MSHORIZN	-0.162	0.343	-0.012	1.907	-0.167	1.087	-0.683	-0.389	0.0

The Q-plot of the residuals provides an effective summary of this information. By fitting a straight line to the plotted residuals, some additional fit information is provided. If the slope of the fitted line is greater than one as represented by the diagonal, the fit is considered good. Slopes less than one are considered poor. In this case, the slope is very nearly one, indicating a fit which is only moderate (LISREL VI manual, p. III.17).

The non-linearity of the plotted data is an indication of specification errors or of departures from normality. In this case, there are six outlying plotted points that exhibit this departure. In all likelihood, these are caused by the departures from normality of the data even after transformation. It should be noted that in this revised model, the determinant of the correlation matrix has improved considerably to .012.

Returning to the other measures of fit in the model, while the chi-square of 343 with 148 degrees of freedom, (Table 5-51) would suggest that the hypothesis that the model represents the data must be rejected, in this case because of the large sample size (165) and because of the difficulties with normality even after transformation, it cannot be used as a primary determinant of model fit (see Bentler and Bonett, 1980, p. 591 or LISREL VI manual, p. I.38).

The goodness of fit index of .832 and adjusted goodness of fit index (adjusted for degrees of freedom) of .784 are better indicators of fit. This is because GFI is independent of the sample size and is relatively robust against departures from normality (LISREL VI manual, p. I.41). The GFI is a measure of the relative amount of variances and covariances accounted for by the model. Since its statistical

TABLE 5-51

FIT INDICES

```
MEASURES OF GOODNESS OF FIT FOR THE WHOLE MODEL :

CHI-SQUARE WITH 148 DEGREES OF FREEDOM IS    343.26 (PROB. LEVEL = 0.000)

GOODNESS OF FIT INDEX IS 0.832

ADJUSTED GOODNESS OF FIT INDEX IS 0.784

ROOT MEAN SQUARE RESIDUAL IS     0.091
```

distribution is unknown, there is no standard to compare it with. Although values range from zero to one, it is difficult to assess various levels except in a comparison with alternate models proposed as explanations for the empirical data. In that regard, the goodness of fit index of the previous model represented by Figure 1 was .763 and the AGFI was .706. The chi-square was calculated as .647 with 222 degrees of freedom for the original model. Clearly there has been substantial improvement in the model fit. However, Bentler and Bonett suggest that models with "overall fit indices of less than .9 can usually be improved substantially" (1980, p. 600).

The values noted above for the revised model are consistent with other assessments of fit for the model.

Turning to estimates of the error terms theta epsilon and theta delta for the measurements (Table 5-52), it is clear that the estimated error parameters are high in relation to the squared multiple correlations for the individual variables which is a measure of the strength of the individual relationships. Reasons for this will be discussed below.

Strong squared multiple correlations for the x and y variables can only be found for those variables which were found to be significant in the T-tests mentioned above. However, the coefficient of determination for the y variables which is a measure of the strength of the relationships jointly is .828 which is much better. Consideration of the squared multiple correlations for the eta variables shows that the strength of the relationships represented by the eta variables (endogenous latent variables), is relatively low at .203 and .308 respectively. In like fashion, the total coefficient of determination

TABLE 5-52

MEASUREMENT ERRORS

PSI

ETA 1	ETA 2
0.609	0.385

THETA EPS

PARTICIP	PPFORMAL	PRCCEDPP	PPMPS	PLANPLAE	PPHIST	GOODPP	GOODRRP	FREQUENT	ECSFORML
0.933	0.704	0.655	0.989	0.792	0.972	0.995	0.933	0.664	0.244

THETA EPS

ECSTIOPP	MPSPERE	MRPCLASS	INVPCT	CUSTDEL
0.998	0.448	0.667	0.892	0.498

THETA DELTA

IMPLTIME	PROGRESS	SOFTMOD	MSHORIZN
0.851	0.667	0.810	0.0

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES

PARTICIP	PPFORMAL	PRCCEDPP	PPMPS	PLANPLAE	PPHIST	GOODPP	GOODRRP	FREQUENT	ECSFORML
0.067	0.296	0.345	0.011	0.208	0.028	0.005	0.067	0.336	0.756

SQUARED MULTIPLE CORRELATIONS FOR Y - VARIABLES

ECSTIOPP	MPSPERE	PRPCLASS	INVPCT	CUSTDEL
0.002	0.552	0.333	0.108	0.502

TOTAL COEFFICIENT OF DETERMINATION FOR Y - VARIABLES IS 0.828

SQUARED MULTIPLE CORRELATIONS FOR X - VARIABLES

IMPLTIME	PROGRESS	SOFTMOD	MSHORIZN
0.149	0.333	0.190	1.000

SQUARED MULTIPLE CORRELATIONS FOR STRUCTURAL EQUATIONS

ETA 1	ETA 2
0.203	0.308

TOTAL COEFFICIENT OF DETERMINATION FOR STRUCTURAL EQUATIONS IS 0.252

for the structural equations is only .252, again relatively low. Further, since all the t-tests for parameter estimates of theta epsilon and theta delta are significant at the .05 level, the model clearly indicates considerable room for improvement.

Interpretation

Interpretation must begin with the factor loadings for each of the latent variables. First for η_1 (the production plan), as mentioned above, production plan formality, production plan regularity and procedures, forecasting formality and forecasting frequency have loaded the most significantly on (are the best representatives for) the latent variable construct. These variables most strongly represent the largest amount of variance of the production plan variables taken as a whole. Additional significance was observed in plan participation and resource requirements planning activity but the magnitudes of the loadings were less.

Eta 1, the production plan, as a construct is meant to represent production planning at its best. That is, the higher the values of the variables used to measure the production plan, the better the production plan should be (with the exception of GOODPP which is the frequency of plan review, an expected negative relationship). Therefore, the degree to which eta 1 is seen to affect the success variables, is the degree to which the production plan variables affects success of system performance.

This information can be directly obtained from consideration of the total effect of eta on y (Table 5-47). Clearly, the influence of eta 1 on the success variables is both significant at the .05 level and has magnitudes which are strong in relation to those of some of the plan variables. The impact of this is to show the close relationship between production plan variables and system success directly. For example, increased forecast formality implies better system performance.

In magnitude, both master schedule performance and customer delivery performance rank just below formality, frequency and regularity of production planning and forecasting and above resource requirements planning and plan participation. MRP class is slightly below that and inventory percent is at the bottom.

It therefore appears that there is a strong relationship between forecast and production planning formality and regularity and successful systems as determined by master schedule performance and customer delivery performance.

It also appears that good resource planning and the degree of plan participation are closely connected with success but to a lesser degree.

Since there was no significant relationships observed in the remaining production plan measurement variables, it appears that there is little which can be said concerning production plan performance, the direct use of the production plan by the master schedule, the absolute frequency of plan review and the length of time that production planning has been done by the firm.

Before concluding that these variables are not important to the planning process or to the success of the system, it would be wise to examine each of these measures separately.

In the case of production plan performance, previous discussion has established that plan performance can be considered a measure of overall system success since the production plan is considered to be part of the MRP system and since it is an outcome measure as opposed to a composition measure of the production plan. This relationship is discussed in greater detail below when the effects of Eta 2, the master schedule horizon is discussed.

The use of the production plan to prepare the master schedule is reported to be a primary reason for doing production planning as indicated above. The magnitude of this estimate is small and not significant as already reported but the nature of the variable measure must be considered.

The variable PPMPS was based on a trimodal scale of 0, 5, 10. Since the variable exhibited a negative skewness, an attempt was made to transform the variable to create greater normality. A squared transformation led to a variable with significant skew still present. This is because, in 128 of the 149 cases, the plan was sent to the master schedule and used in its preparation. This overwhelming response creates a negative skew.

The real issue then is two fold. First is the issue of LISREL's behavior in this type of analysis and second is the issue of the value of the results when the vast majority of the responses used the plan as it was intended.

The correlation matrix used as input in the LISREL VI program is based, in the case of MPSPP, on polyserial correlation. In such case, departures from normality become especially critical and the parameter estimates are cast in doubt. Since also, the vast majority of the responses indicated that the production plan is used directly in preparation of the master schedule, discrimination on success is relatively non-critical. Accordingly, the conclusion is that the use of the production plan in preparation of the master schedule is more or less a "given" and the ISREL VI analysis is cast in doubt on this issue.

In the case of GOODPP, the measure of the frequency of planning, a weak relationship between less frequent planning and successful production planning appears to exist. It was expected that a negative relationship would exist indicating that the less frequently the plan is done, the less successful would be the plan.

All that can be concluded is that this factor does not load greatly onto the plan construct and its estimate is not significant. Conclusions as to implications for this variable cannot be made beyond this point.

Lastly, the variable FCSTTOPP, the use of the forecast in the preparation of the production plan presents the same polyserial problems as were presented above for PPMPS. In this case, 140 of 150 respondents indicated that the forecast was directly used in preparation of the production plan.

In summary then, it would appear that those firms which do production planning formally and regularly and also do forecasting formally and regularly are more often associated with success than those which do not. Additionally, those firms which do resource requirements planning each time they do production planning and who also have participation from all major functions of the company are more often successful than those who do not. Most all of the respondents indicated that the production plan was used directly in the preparation of the master schedule and that the forecast is used directly in the preparation of the production plan. As such this seems to be a base condition of the model. The analysis did not indicate a strong relationship or a significant one so little can be said beyond that which has already been stated.

Turning to the analysis of the variables which represent the hypothetical constructs of the exogenous variables of the model, implementation success was represented nearly evenly by its three measures, implementation time, progress and software modification. All three were significant factor loadings (at the .05 level) on the general construct. T-values exceeded 4 in all cases.

Of the three, PROGRESS (the number of MRP system modules which are operational and being used regularly) had the smallest measurement error (see Table 5-52).

Implementation time (the length of time that implementation was ongoing) had the highest measurement error. This measure was given in months and depended on the memory of the respondent to answer. Respondent bias may also be present where the respondent was interested in providing an estimate consistent with what he believed to be acceptable implementation times for an MRP system.

The error in the estimate of software modification was also high at .810. This response was based on a Likert scale with four points and requires the respondent to interpret between terms such as "some" and "a great deal of." Additionally it requires respondent knowledge and is different than most of the other scales in the study in that it was done on a 4 point scale where most of the other Likert scales are 5 point. This decreases discrimination in measurement.

No total coefficient of determination for the x-variables is given by the program so an overall estimate of the degree to which all the x variables represent the constructs cannot be determined.

Little can be said about the value of the MSHORIZN, master schedule horizon construct since it is only represented by a single variable and must be set to one to make the solution positive definite. In all of the estimates it appears as a one. As indicated above, the model suffers from this single measure.

The heart of the analysis is the interpretation of the path coefficients represented by the gammas and betas in the model. Of primary interest in these variables is β_{21} the effect of the production plan on system success. On an absolute basis the magnitude is not large but the estimate is significant at the .001 level. Consideration of either the standardized solution or of the ML estimates yields the most significant information when comparisons are made between the magnitudes of the effects.

In the case of γ_{11}, the effect of implementation success on the production plan, the magnitude of the effect is slightly larger than the magnitude of the influence of the production plan on success. Furthermore, γ_{11} is significant at the .001 level also. Consideration of total effects, Table 5-47, shows that the influence of implementation success on system success occurs largely through the effects of the production plan since the magnitude of the direct effect of implementation success on system success is less than those of the total effect of implementation success on system success. It appears then, that system success is more strongly associated with production plan success than with implementation success. The ML estimates of the effects of implementation success on system success were only significant at the .1 level.

Given this information, the interpretation appears that while both implementation success and production plan influence success of the system, implementation success does so through the development of the production plan. The implication is clear. The production plan should be considered as part of the overall MRP system and implementation should include its development to maximize success of the system.

The overall influence of the master schedule horizon appears to be small and to be insignificant at the .05 level. This leads to consideration of dropping the construct as part of the model especially with the problems of a single measure. This could not be justified when the standard solution (Table 5-48) was considered. Clearly, the magnitude of the effect of the master schedule horizon on system success is too high to allow it to be eliminated from the model. The magnitude of this effect is most likely due to the association between master schedule horizon and master schedule performance.

The effects of the master schedule horizon on the production plan are very small and non-significant. This may be due to several reasons beyond those of general theory. The variable was nominal in form once again leading to polyserial correlation problems. Like the ordinal variables discussed above, a large proportion of the respondents had master schedules whose lead time was greater than the total lead time of their products (136 of 153 cases). Accordingly, the same logic applies to this analysis; namely that master schedule horizons in excess of total lead time appear to be the norm and little information can be garnered by the analysis.

We turn now to the conclusions gained from the study and an evaluation of the original hypotheses along with recommendations for future study.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The central focus of the study has been the production plan, its characteristics and relationship to MRP system success. The hypotheses were not stated in the typical null form with tests to reject the null, but were stated in a form consistent with the LISREL methodology. That is, each hypothesis was stated to show the expected relationship between the variables of the model. The model was then tested to determine if the data supported the relationships hypothesized in the model.

The hypotheses are reproduced here for convenience.

> H1: A company with a production plan has a higher level of MRP system performance than a company without a production plan.

The remaining hypotheses relate to the characteristics of the production plan.

> H2: The period of formulation/review of the production plan is important to the success of the MRP system. To be most effective, the plan should be formulated or reviewed monthly or at worst quarterly.

> H3: The participants in the formulation or review of the production plan should be representatives of the major functional areas of the company. These include: marketing/sales, operations/production, finance/accounting, engineering/R&D, materials and the chief operating officer. The more functions that are represented, the greater the success of the production plan and the MRP system.

H4: More formal production plans lead to more successful production plans and more successful MRP systems.

H5: Production plans which have more strict procedures which are regularly followed are more successful and lead to more successful MRP systems.

H6: Production plans which are used in the preparation of the master schedule are more strongly associated with successful MRP systems.

H7: Production plans which have resource requirements planning done each time production planning is done are more successful and lead to more successful MRP systems.

H8: Production plans which are prepared with formal and regular forecasting are more successful and lead to more successful MRP systems.

H9: Better production plan performance leads to better MRP system performance.

Hypotheses Conclusions

There were several good indications that the first hypothesis was supported in the study. This is critical to the study since it establishes the important link between the production plan and MRP system success which is integral to many of the remaining hypotheses. Most significantly, both the discriminant analysis and the LISREL analysis showed support for the hypothesis.

The one way ANOVA showed significant differences between the means in the case of master schedule performance, customer delivery performance and MRP class. In all cases the values of the means of these variables were higher for the companies with a production plan than for those without a plan.

The calculated discriminant scores used to predict the group of the individual cases was successful 65 percent of the time vs. an expected 50 percent of the time which would occur with no information. This indicated modest support for the hypothesis that companies with production plans outperform those without, at least for the sample used in the study.

Finally in the LISREL analysis, the effect of the production plan construct on the system success construct was large and positive in both models used. It was the largest of the beta parameters calculated in the original model which incorporated firm complexity information (see Table 5-41). It was the only beta parameter estimated by LISREL in the second model but it was among the largest parameter values estimated. In both models, the parameter was significant at the .05 level. This indicates that there is a strong direct effect of production planning on MRP system success.

While the hypothesis seems to be supported in this case, there are problems which cannot be overlooked. The measurement error in the LISREL model was extremely high for many of the variables as discussed in Chapter 5. Further, the overall fit of the model to the data was only fair as already shown. Accordingly, results must be interpreted cautiously. It appears however, that the data gathered from the sample and analyzed by LISREL tends to support the hypothesis that those firms with production plans outperform those without.

One issue that arose in the ANOVA analysis merits further discussion. The ANOVA analysis did not support the hypothesis that inventory performance of the reduced sample was different from that of the full sample. A possible explanation of this result may be that in all firms, regardless of system success, inventory performance is a main focus of management. Thus, companies with and without production plans tend to perform similarly in this regard. Those firms without good systems may be achieving these results at far greater expense than those with but it is difficult, if not impossible, to determine that with the data gathered in the study.

The H2 hypothesis that the period of plan formulation is important to the success of the plan was not supported by the analysis. This hypothesis was represented by the variable GOODPP which was taken as the absolute value of the difference between monthly and the period of review given by the firm. If the hypothesis was to be supported one would expect that the parameter estimated (lambda y) would be negative and significant. It was neither as reference to Table 5-44 shows. The error term was extremely high at .995 (see Table 5-52). All that can be said is that the analysis did not support the hypothesis that the period of review is important to the success of the MRP system.

There was stronger support for the H3 hypothesis on participation than for the previous hypothesis. The estimated parameter was significant at the .05 level although the value of the parameter PARTICIP was among the lowest estimated that was still significant. This would seem to indicate that there is limited support for the hypothesis that the more functional areas that participate in the plan, the more likely it is to be successful and consequently influence the success of the MRP system.

For H4, plan formality, represented by the value of the parameter estimate of PPFORMAL in the model, was found to be quite high in relation to all the other measures of the production plan. Additionally, it was significant at the .001 level. This would seem to indicate that H4 is supported i.e., plan formality is important to a successful production plan and ultimately a successful MRP system (based on conclusions above for H1).

H5 also has strong support. In fact, this parameter was estimated by the model with the second highest value. It was significant at the .001 level also. It would appear that those firms which have production plans with strict procedures which are always followed are more strongly associated with successful production plans and successful MRP systems.

Hypothesis H6 that production plans used in preparation of the master schedule lead to more effective MRP system performance is more difficult to support. The analysis was confounded by the polyserial correlation problem discussed in Chapter 5 and by the fact that the distribution was non-normal. However, 86 percent of the firms responding with production plans indicated that the plan was used in preparation of the master schedule. Given the nature of these facts, it is difficult to interpret the low, value of PPMPS estimated by the LISREL model. Not only is the estimate low but it is only significant at the .1 level. In addition, the measurement error is high.

Perhaps the best that can be said is that since most of the firms who had a production plan in the sample used it in preparation of the master schedule, and the performance of all the firms in the sample was varied, then the use of the plan to prepare the master schedule may be a "given" and is independent of MRP system success. It may be more of a precondition to the operation of the plan.

In the case of resource requirements planning (H7) the support is stronger. The LISREL estimate is the same as that for participation and is significant at the .05 level. This lends modest support to the hypothesis that those firms which do resource planning at the same time as the production plan is done are more strongly associated with success than those firms who do RRP less frequently or not at all (H7).

Results for the forecasting variables (H8) were the highest of all the parameters estimated. Forecast formality had the highest parameter estimate of all and was significant at the .001 level. This would seem to indicate that forecast formality is very important to the success of the production plan and to the success of the MRP system through the production plan.

Forecast frequency had the third highest parameter estimate and was also significant at the .001 level. Taken together, there is good indication that the forecasting activity is very important to the production planning activity and ultimately to successful systems.

H8 must be interpreted much the same way as the use of the production plan to prepare the master schedule was interpreted in H6 above. Nine-three percent of the sample used the forecast to prepare the production plan and so, in spite of the low parameter estimate of FCSTTOPP, the hypothesis that the forecast should be used in the preparation of the production plan and is important to the success of the planning system can probably be considered a condition for the successful system. Overall, this means support for H8.

Hypothesis H9 indicates that better production plan performance leads to better MRP system performance. Based on the LISREL analysis, a better statement may be that production plan performance is one indicator of overall MRP system performance. In fact, as will be discussed shortly, implementation and operation of the production plan is a very important part of overall MRP implementation and integral to MRP system success. Thus the H9 hypothesis must be rejected as stated and the alternate statement above should be substituted.

Other Relationships

As indicated in Chapter 5, several other relationships were explored in the analysis. These were firm complexity, implementation success and master schedule horizon considerations.

The data used to evaluate the model did not support the contention that firm complexity as represented by the number of parts, number of end items, number of salaried personnel and number of hourly personnel affected any of the other constructs of the model. Firm complexity was expected to affect all the other constructs; e.g., higher complexity was expected to adversely influence implementation success and overall MRP system success. Such was not the case.

The conclusion indicated by the absence of this relationship is that in spite of high complexity in a firm, MRP implementation can succeed, a production plan can be established and MRP success can be achieved probably by using the implementation advice so prevalent in the literature.

Implementation success, however, was shown to be important to the success of the production plan and to MRP system success both directly and indirectly. The strongest effects that were observed in the study were those of implementation success on the production plan and the production plan on MRP system success. Both of these parameter estimates were significant at the .001 level. The implications are clear. Overall MRP system success as defined by master schedule performance, customer delivery performance and MRP class appraisal is dependent upon the production plan which must be seen as an integral and important part of the MRP system. Successful implementation of the TOTAL system then leads to overall MRP system success.

There were little or no observed effects of the master schedule horizon on the production plan and on MRP system success. There was a small effect estimated between the master schedule horizon and MRP system success but it was only significant at the .1 level. This effect was probably due to the relationship between master schedule horizon and master schedule performance (part of the measure of MRP system success). The small effect precluded further reduction of the model.

The strongest conclusion which can be drawn from the master schedule horizon construct is that while it appears that the sample used did not show support for the model hypothesis that the master schedule horizon construct affects the production plan or MRP system success, this may be more because it was modeled by a single variable and did not include backlog information as originally intended, than because of the construct itself. This is considered to be a serious drawback to the study.

Difficulties and Recommendations

There were a number of difficulties (problems) with the study. First, the rate of return of the questionnaire was a little more than

10 percent. This was directly attributed to the length of the questionnaire which was seven pages long. Future questionnaires should be more focused and shorter.

Next, one of the major problems with the study is the very high degree of measurement error uncovered in the analysis. The measurement error is estimated to be mostly due to respondent lack of knowledge or memory fallibility. Overcoming this problem would require intensive follow-up with each respondent, either personally or via telephone communication, to verify each of the responses in the critical measures of the questionnaire. This, in turn, would be extremely costly and time consuming.

One minor conclusion may be that because of the high frequency of estimated performance information, it may be that most firms do not normally track performance formally or if they do, such information is not made available for general consumption.

Future studies of these issues might be better accomplished and measurement error reduced, if the questionnaire was reduced in scope the sample made smaller (perhaps limited to those firms which were prequalified as representative of different levels of production plan activity), and the questionnaire completed via personal interview.

Respondent bias was a concern throughout the study. Efforts were made to either control it or to explain it where it was suspected. The nature of survey research is such that respondent bias is an everpresent issue. Future studies must be even more vigilant on this problem.

The overall fit of the model was only fair. Improvements would be accomplished by a substantial reduction in measurement error.

Beyond that, other models, with other variables may be developed which fit the data better than the model suggested. Such models are not obvious to the researcher, but it's hoped that future research may uncover evidence suggesting other models.

Future Research

The original intent of this study was to take a broad cut at the issues of production planning. This broad cut was expected to expose a number of issues which could be explored in future research.

There are several research studies which have been suggested by the results of this study. First, the conclusions drawn from the study should be verified by smaller, more focused and intensive studies as suggested above.

Next, the entire planning process in an MRP II environment should be studied. This is especially true of the linkages between the strategic plan and the production plan. Some of the data collected in the current study and not used in the analysis may be evaluated to explore the issue of the strategic plan, production plan relationship.

Finally, a number of issues concerned with the development of the production plan during the MRP II system implementation deserve further study. These issues include questions such as when, during implementation, should the production plan be developed and to what extent is the production plan considered to be part of the overall MRP II system implementation. These issues are considered to be important in light of the finding that the production plan influences overall MRP system success.

APPENDIX

MICHIGAN STATE UNIVERSITY

GRADUATE SCHOOL OF BUSINESS ADMINISTRATION
DEPARTMENT OF MANAGEMENT (517) 355-5415

EAST LANSING · MICHIGAN · 48824 1121

Dear MRP User,

(Even if your company, division or plant is not an MRP user - PLEASE read on!)

I need your help and maybe I can do something for you!

Trying to find out what works and what doesn't was a concern for me during my 21 years in industry. Now that I have returned to school (to get my PhD in Production/Operations Management), I am trying to get those answers and am asking you to please help me by taking some of your time to complete the enclosed questionnaire which is part of my thesis. In return, if you are interested, I will send you a copy of the results which may help in your manufacturing planning.

This questionnaire is designed to be completed by someone who is familiar with the planning systems of the company (MRP, Master Schedule, Production Plan and Strategic Plan). If you are not such a person, please pass this questionnaire on to such a person (often this is the Materials Manager). The results of the questionnaire will be held in strict confidence and no company information will be published except in aggregate form with individual company identifications withheld.

If you want the results, fill in your name, title and address at the bottom of this page and I will send them to you.

Thank you for your help!

Sincerely,

Ronald T. Pannesi

Name ____________________

Title ____________________

Company ____________________

Address ____________________

____

____

PRODUCTION PLAN
QUESTIONNAIRE

This questionnaire is designed to be answered by the Materials Manager, Production and Inventory Control Manager, or another person who is most familiar with the MRP system and the other planning systems in your company. If you encounter questions which do not apply to your company, please leave them blank unless otherwise indicated. Answer the remaining questions by entering or circling the most appropriate responses. When you have completed the questionnaire, please return it in the prepaid return envelope. Thank you for your help.

Part A: COMPANY DESCRIPTION

1. Your Title ______________________________
   Your Name ______________________________

2. Your Company's Industry ______________________________
   Your Company's SIC code (if known) ______________________________

3. Please answer the remainder of the questionnaire for the facility you are most familiar with or responsible for, unless otherwise indicated.

   The facility described in the remainder of this questionnaire is:

   a. Single Plant b. Multiple Plants
   c. Other (please describe)

4. Annual Sales

   Total Company $ ______________
   Your Facility $ ______________

5. Type of Products (circle all that apply)

   a. Make to Stock b. Make to Order
   c. Assemble to Order d. Engineer to Order

6. The Type of Process in a company can be described by volume of product from a single unit, job shop to a very high volume continuous process (like an oil refinery). Please indicate with a check mark on the line below the position that most nearly describes your MAJOR product volume/process.

Mfg. Process	Volume		
Job Shop	Low	Medium	High
Batch Manufacturing	Low	Medium	High
Repetitive Mfg. (or High Volume Assembly Line)	Low	Medium	High
Continuous Process	Low	Medium	High

7. Approximate number of possible "end items" that are Master Scheduled (excluding service/spare parts) __________

8. Approximate number of different part, component and assembly numbers __________

PART B MRP SYSTEM

MRP is defined here in the broad sense as a system built around material requirements planning and also including the additional planning functions of Production Planning, Master Production Scheduling and Capacity Planning as well as the execution functions of Shop Floor Dispatching and Control and Purchasing Follow-up and control.

1. a. When did the MRP Implementation project formally start?
   (Give approximate date) ______________________________

   b. When was the project concluded and implementation completed?
   (Give approximate date. If the project is still formally ongoing, please indicate.)
   Date implementation completed ______________________________
   Implementation ongoing ☐

2. Approximately how many employees are there at the implementing facility?
   Salaried (Indirect) ____________________ Hourly (Direct Labor) ____________________

3. To what degree have you modified your standard MRP software?
   (Please indicate with a check mark on the line below.)

no modification Used Vendor package off the shelf	some modification	a great deal of modification	completely developed in house

4. Which of the following features does your MRP system have (including in-house developed software) and which do you use?

Feature	Our system has	We use	We update or run this module (frequency)
Forecasting			
Rough Cut Capacity Planning			
Master Production Schedule			
Production Plan			
Purchasing			
Shop Floor Control			
Material Requirements Planning			
Capacity Requirements Planning			

5. Internal Lead Time is defined as the time it takes to produce a product with all purchased items available. Approximately how long in weeks is the Internal Lead Time of your major product line?
   ________ weeks

6. What is the Total Lead Time (includes the lead time for purchased items) for your major product line?
   ________ weeks

7. How far into the future does the Master Production Schedule extend?
   ________ weeks

Part C SYSTEM PERFORMANCE

1. The following categories are based on Oliver Wight's Class A, B, C or D companies.

Class A: Closed Loop system used for both priority planning and capacity planning. MPS is leveled and used by top management to run the business. Most deliveries are on time, inventory is under good control, and little or no expediting is done.

Class B: Closed Loop system with capability for both priority planning and capacity planning. However, MPS is somewhat inflated. Top management does not give full support. Some inventory reductions have been obtained but capacity is sometimes exceeded and some expediting is needed.

Class C: Order launching system with priority planning only. Capacity planning is done informally with a probably inflated Master Production Schedule. Expediting is used to control the flow of work. A modest reduction in inventory has been achieved.

Class D: The MRP system exists mainly in data processing. Many records are inaccurate. The informal system is largely used to run the company. Little benefit is obtained from the MRP system.

Which of the above categories best describes the status of MRP in your facility? Please check the place on the line below that most nearly describes the current status of your MRP system.

|—|—|—|—|—|—|—|—|—|—|
D C B A

2. The Master Production Schedule calls for the completion of certain product or jobs during each MPS planning period. The per cent completed as scheduled, of the products jobs is called Master Production Schedule Performance. What is the AVERAGE measured Master Schedule performance of your facility?

   Last month __________ % of MPS was completed as scheduled

   2 months ago__________ % of MPS was completed as scheduled

   3 months ago__________ % of MPS was completed as scheduled

   (if formal measurements of Master Production Schedule performance are not made, please estimate the performance numbers and indicate with an "E")*

3. How often are inventory goals set for your facility?

   every ______________ weeks

4. Are inventory goals set in terms of:

   a. inventory dollars

   b. inventory turns

   c. some other measure (please indicate)

5. On average, inventory goals at our facility are MET within ________________________________ % of target.

   Note: If no formal measurements are made, please estimate this number and indicate with an "E" if estimated.

6. In your company, do Sales and Manufacturing use the same promise date for customer delivery? ☐ yes ☐ no

7. If so, on average, approximately what per cent of customer deliveries are shipped on time? ____________________ %

   Note: If formal measurements are not made, please estimate this number and indicate with an "E" if estimated.

8. If not, on average, what per cent of customer deliveries are shipped on time to the Sales promise?______________ %

   to Manufacturing promise?______________ %

   Note: if formal measurements are not made, please estimate this number and indicate with an "E" if estimated.

Part D THE PRODUCTION PLAN

Please read the following definition carefully

The Production Plan is the Plan which results from the setting of the overall level of manufacturing output. Its prime purpose is to establish production rates that will achieve management's objective in terms of raising or lowering inventories or backlogs, while usually attempting to keep the production force relatively stable.

The Production Plan is usually stated in broad terms (e.g., product groupings, families of products). It must extend through a planning horizon sufficient to plan the labor, equipment, facilities, material, and finances required to accomplish the Production Plan. Various units of measure are used to express the plan such as standard hours, tonnage, units, pieces, dollars, etc.

As this plan affects all company functions, it is normally prepared with information from marketing, manufacturing, engineering, finance, materials, etc. In turn, the Production Plan becomes management's authorization for the Master Production Scheduler to convert into a more detailed plan.

1. Does your facility have a plan similar in nature to the Production Plan described above? ☐ yes ☐ no *If no, go to Question 10.*

2. What is it called? ______________________________

3. a. In weeks, how often is the Plan formulated/reformulated? ________ weeks

   b. What time horizon (how far into the future) does the Plan cover? ________ weeks

4. Who participates in its formulation and/or must approve the Plan?

Function	Title of Person Who Participates in Plan Formulation	Title of Person Who Approves Plan Formulation	Check Here If This Function does not Participate
a. Marketing/Sales			
b. Production/Operations			
c. Finance/Accounting			
d. R&D/Design Engineering			
e. Chief Operating Officer			
f. Master Production Scheduler			
g. Materials			
h. Other			

5. How formal is the Production Plan?

very informal usually sent verbally		somewhat formal sometimes written sometimes verbal		very formal always written

no procedures		some procedures irregularly followed		strict procedures always followed

6. a. **Does the Master Production Scheduler receive the completed Production Plan?** ☐ yes ☐ no

   b. **Does the Master Production Scheduler use the Production Plan to prepare the Master Production Schedule?** ☐ yes ☐ no

   c. What other departments or groups receive the Production Plan each time that it is formulated/reformulated and what do they use the Plan for?

Department/Group	Uses
1.	
2.	
3.	
4.	
5.	

7. Is actual performance against the Production Plan measured? ☐ yes ☐ no

8. If the answer to question 7 is yes, what is the average performance (in percent of Plan achieved) of the facility to the
Production Plan during the last planning period? ________ %
the previous planning period? ________ %
the planning period before that? ________ %

Note: If formal measurements are not made, please estimate these numbers and indicate with an "E".

9. a. In what units is the Production Plan stated? (e.g. standard hours, dollars, assembly hours etc.) If the Plan is stated in more than one kind of unit, please indicate all which are used.

____

b. Is the Production Plan formulated for:
1. families of products?
2. individual products
3. mix
4. other (please specify)

c. How long has the company or facility been doing Production Planning? ________________

Resource Requirements Planning is the conversion of the Production Plan into capacity needs for key resources: manpower, machinery, warehouse space, facilities, vendors' capabilities and money and is used to evaluate the Plan prior to attempting to implement it.

10. Does your company do Resource Requirements Planning? ☐ yes ☐ no

** If the answer is no, please go to Question 13. **

11. If yes, how often and when is it done? (answer can be stated in weeks or can be related to some other planning activity such as "each time Production Planning is done") ____

____

____

12. By job title, who is responsible for doing Resource Requirements Planning? ________________________

____

13. If your COMPANY forecasts sales, how formally and regularly is it done?

not at all	irregularly	occasionally	frequently	regularly

very informal no procedures		somewhat formal some procedures		very formal strict procedures

14. If your FACILITY forecasts sales, how formal and regularly is it done?

not at all	irregularly	occasionally	frequently	regularly

very informal no procedures		some procedures		very formal strict procedures

15. a. What departments and/or groups are responsible for forecasting sales
for your company? ________________________________
for your facility? ________________________________

b. How far into the future does the forecast cover
for your company? ________________________________
for your facility? ________________________________

16. Is Sales Forecasting done for (Circle all that apply)	Check here if sales forecast accuracy is formally evaluated	What is the average accuracy of sales forecasts over the last 3 forecast periods? (Estimate if necessary and Mark with an "E")	What percent of total sales is each of the following categories?
a. families of products			
b. end items			%
c. service/spare parts			%
d. other (please state)			%
			TOTAL 100%

17. Is sales forecast information used to formulate any of the following plans? (circle all that apply)
   a. The Strategic Plan
   b. The Production Plan
   c. The Master Production Schedule
   d. Other (please specify)

Part E: STRATEGIC PLANNING

1. a. Does your company have a Strategic Plan? ☐ yes ☐ no
   b. Does your facility? ☐ yes ☐ no
   c. How far into the future does the Strategic Plan extend?
   ____

2. By title, who participates in the formulation of the Strategic Plan?

   Title
   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________
   5. ______________________________
   6. ______________________________

3. How formally and regularly is Strategic Planning done?

very informal no procedures	somewhat formal some procedures	very formal strict procedures

not at all	irregularly	occasionally	frequently	regularly

4. How often is the Strategic Plan reviewed/revised for your company? ________ weeks
   for your facility? ________ weeks

5 Is the Strategic Plan DIRECTLY used in preparation of (circle all that apply)

a. The Production Plan

b. The Master Schedule

c. The Marketing Sales Plan

d. The Financial Plan

e. Budgets

f. R&D Engineering Plan

g. Human Resource Planning

h. Other (please indicate)

THANK YOU VERY MUCH!

BIBLIOGRAPHY

BIBLIOGRAPHY

Abair, Robert A. and Helle, Phillip F., "Capacity Planning: A Common Sense Approach to Manufacturing Planning," Readings in Material and Capacity Requirements Planning. APICS 27th Annual International Conference Proceedings, American Production and Inventory Control Society, October 9-12, 1984, pp. 65-67.

Anderson, John C.; Schroeder, Roger G.; Tupy, Sharon E. and White, Edna M.; Material Requirements Planning - A Study of Implementation and Practice, American Production and Inventory Control Society, 1978.

Andrew, Charles G., "Strategy Structure and Systems - Integrating Production into the Corporate Game Plan," APICS 22nd Annual International Conference Proceedings, APICS, 1979, pp. 237-240.

APICS Dictionary, Fifth Edition, Thomas F. Wallace, Editor, American Production and Inventory Control Society, 1984.

Axsater, Sven, "Aggregation and Disaggregation in Hierarchical Production Planning," European Journal of Operational Research, Vol. 17, No. 3, September 1984, pp. 338-350.

Axsater, Sven, "Aggregation of Product Data for Hierarchical Production Planning," Operations Research, Vol. 29, No. 4, August 1981, pp. 744-756.

Bacigalupo, Paul F., "Master Production Planning and Scheduling for the '80's," APICS 25th Annual International Conference Proceedings APICS, 1982, pp. 340-343.

Babbie, Earl R., Survey Research Methods, Belmont (California: Wadsworth Publishing Company, Inc., 1973).

Bagozzi, Richard P., Causal Models in Marketing (New York: John Wiley and Sons, 1980).

Bentler, P. M. and Bonnett, "Significance Tests and Goodness of Fit in the Analysis of Covariance Structures," Psychological Bulletin, 1980, Vol. 88, No. 3, pp. 588-606.

Berry, William L.; Vollmann, Thomas E. and Whybark, D. Clay; Master Production Scheduling - Principles and Practice, American Production and Inventory Control Society, 1979.

Bitran, Gabrial R.; Haas, Elizabeth A. and Hax, Arnoldo C.; "Hierarchical Production Planning: A Two-Stage System," Operations Research, Vol. 30, No. 2, March/April 1982, pp. 232-251.

Bitran, Gabrial R.; Haas, Elizabeth A. and Hax, Arnoldo C.; "Hierarchical Production Planning: A Single Stage System," Operations Research, Vol. 29, No. 4, July/August 1981, pp. 717-743.

Bitran, Gabrial R. and Hax, Arnoldo C., "On the Design of Hierarchical Production Planning Systems," Decision Sciences, Vol. 8, No. 1, pp. 28-55, January 1977.

Bourgeouis, L. J. and Brodwin, David R., "Strategic Implementation: Five Approaches to an Elusive Phenomenon," Strategic Management Journal, Vol. 5, No. 3, July-September 1984, pp. 241-264.

Bourgeouis, L. J., "On the Measurement of Organizational Slack," Academy of Management Review, Vol. 6, No. 1, pp. 29-39.

Bowman, M. J., "Consistency and Optimality in Managerial Decision Making," Management Science, Vol. 9, 1963, pp. 310-321.

Case, Towner, B., "What is This Thing Called Manufacturing Resource Planning," APICS 23rd Annual International Conference Proceedings, APICS, 1980, pp. 166-169.

Chakravarthy, B., "Adaptation: A Promising Metaphor for Strategic Management," Academy of Management Review, Vol. 7, No. 1, pp. 35-44.

Chopra, Vinnie, "Master Production Scheduling: A Management Perspective," APICS 25th Annual International Conference Proceedings, APICS, 1980, pp. 328-331.

Clark, Steven J.; Cox, James F.; Jesse, Richard R. and Zmud, Robert W.; "How to Evaluate your Material Requirements Planning System," Production and Inventory Management, Third Quarter 1982, Journal of the American Production and Inventory Control Society, Vol. 23, No. 1, pp. 15-34.

Deziel, D. P. and Eilon, S., "A Linear Production-Inventory Control Rule," The Production Engineer, Vol. 46, 1967, pp. 93-104.

Dillon, William R. and Goldstein, Matthew, Multivariate Analysis Methods and Applications (New York: John Wiley & Sons, 1984).

Donkersloot, Richard Jr., "Productivity Through Manufacturing Control," Production and Inventory Management, First Quarter 1983, Journal of the American Production and Inventory Control Society, Vol. 24, No. 1, pp. 103-117.

Ebert, Ronald J., "Time Horizon: Implications for Aggregate Scheduling Effectiveness," AIIE Transactions, Vol. 4, December 1972, pp. 298-307.

Ebert, Ronald J., "Aggregate Planning with Learning Curve Productivity," Management Science, Vol. 23, No. 2, October 1976, pp. 171-182.

Eilon, Samual, "Five Approaches to Aggregate Production Planning," AIIE Transactions, Vol. 7, No. 2, June 1975.

Everdall, Romeyn and Ryde, Judith A., "The Production Plan - The Top Management Interface," APICS 25th Annual International Conference Proceedings, APICS, 1982, pp. 231-238.

Fornell, Claes and Larcker, David F., "Structural Equation Models with Unobservable Variables and Measurement Error: Algebra and Statistics," Journal of Marketing Research, August 1981, pp. 382-388.

Garwood, R. D., Hotlist (Atlanta: R. D. Garwood, Inc., November 1977).

Gelders, Ludo F. and Wassenhove, Luk N., "Hierarchical Integration in Production Planning: Theory and Practice," Journal of Operations Management, Vol. 3, No. 1, November 1982, pp. 27-35.

Glueck, William F. and Jauch, Lawrence R., Business Policy and Strategic Management, Fourth Edition (New York, New York: McGraw-Hill Book Company, 1984.

Hall, R. W. and Vollmann, T. E., "Planning Your Material Requirements," Harvard Business Review, 1978, 56(5), pp. 105-112.

Hayes, Robert H. and Wheelwright, Steven C., Restoring our Competitive Edge Competing Through Manufacturing (New York: John Wiley and Sons, 1984).

Hax, A. C. and Meal, H. C., "Hierarchical Integration of Production Planning and Scheduling," M. A. Geisler, Editor in Studies in Management Sciences, Vol. 1, Logistics, North Holland - American Elsevier, 1975, pp. 53-69.

Hill, Richard E., "Production/Operations Functions as Strategic Weapons," Academy of Management Proceedings, 1982.

Hubbs, J. M. and Heany, D. F., "Coupling Strategy to Operation Plans," Harvard Business Review, 1977.

Hofer, C., "Toward a Contingency Theory of Business Strategy," Academy of Management Journal, Vol. 18, No. 4, December 1974, pp. 784-810.

Holt, C. C.; Modigliani, G.; Muth, J. F. and Simon, H. A.; "A Linear Decision Rule for Production and Employment Scheduling," Management Science, Vol. 2, No. 1, October 1955, pp. 1-30.

Hooke, R. and Jeeves, T. A., "'Direct Search' Solution of Numerical and Statistical Problems," Journal of the Association of Computing Machinery, Vol. 8, 1961, pp. 212-229.

Hoyt, Bradley, R., "A Generalized Model for Strategic Planning in the Area of Production and Inventory Control Systems," APICS 21st Annual International Conference Proceedings, APICS, 1978, pp. 472-480.

Howser, Kenneth J., "Avoid the Rocks While Installing MRP II," APICS 25th Annual International Conference Proceedings, APICS, 1982, pp. 129-130.

Iemmolo, George R., "Master Planning from Theory to Practice," APICS 26th Annual International Conference Proceedings, November 1-4, 1983, pp. 26-29.

Jones, Curtis H., "Parametric Production Planning," Management Science, Vol. 13, No. 11, July 1967.

Joreskog, Karl G. and Sorbom, Dag, LISREL VI, Analysis of Linear Structural Relationships by the Method of Maximum Likelihood (Mooresville, Indiana: Scientific Software, Inc., 1985).

Joreskog, Karl G. and Sorbom, Dag, Advances in Factor Analysis and Structural Equation Models (Cambridge, Mass.: Abt Books, 1979).

Kenny, David A., Correlation and Causality (New York: John Wiley & Sons, 1979).

Kinsey, John W., "Master Production Planning - The Key to Successful Master Scheduling," APICS 24th Annual International Conference Proceedings, APICS, 1981, pp. 81-85.

Kneppelt, Leland R., "Production Planning - Master of MPS," APICS 25th International Conference Proceedings, APICS, 1982, pp. 337-339.

Kneppelt, Leland, R., "Implementing Manufacturing Resource Planning/ Difficulty of the Task," Production and Inventory Management, Second Quarter 1981, Journal of the American Production and Inventory Control Society, Vol. 23, No. 2, pp. 59-77.

Krajewski, LeRoy J. and Ritzman, Larry P., "Dissaggregation in Manufacturing and Service Organizations: Survey of Problems and Research," Decision Sciences, Vol. 8, No. 1, January 1977, pp. 1-18.

Krupp, James A. G., "Strategic Business Planning," Production and Inventory Management, Second Quarter 1982, Journal of the American Production and Control Society, Vol. 23, No. 2, pp. 22-35.

Landvater, Darryl, "MRP II - The Software that Ties it All Together," Modern Materials Handling, Cahners Publishing, September 1979.

Ling, Richard C., "The Production Planning Process - Top Management's Role," APICS 25th Annual International Conference Proceedings, APICS, 1982, pp. 447-448.

Ling, Richard C. and Widmer, Kemble II, "Master Scheduling in a Make-to-Order Plant," APICS 17th Annual International Conference Proceedings, APICS, 1974, pp. 320-334.

Lyles, Marjorie A. and Watson, Kathleen M., "Strategy Implementation - The Interface with Human Resources," American Institute of Decision Sciences Proceedings, November 1982.

Malko, Richard W., "Master Production Schedule: A Management Tool," APICS 24th Annual International Conference Proceedings, APICS, 1981, pp. 88-89.

Mather, Hal F. and Plossl, George W., The Master Production Schedule - Management's Handle on the Business, Revised Edition (Atlanta: Mather & Plossl, Inc., 1978).

McBurney, David A., "Linking the MPS to the Production Plan," Scheduling Activities and Techniques, Auerbach Publishers, Inc., 1983.

McClain, John O. and Thomas, Joseph, "Horizon Effects in Aggregate Production Planning with Seasonal Demand," Management Science, Vol. 23, No. 7, March 1977.

Mellichamp, Joseph M. and Love, Robert M., "Production Switching Heuristics for the Aggregate Planning Problem," Management Science, Vol. 24, No. 12, August 1978, pp. 1242-1251.

Melnyk, Steven A. and Gonzalez, Richard F., "In Search of MRP II," Readings in Productivity Improvements, APICS 27th Annual International Conference Proceedings, APICS, October 9-12, 1984, pp. 125-129.

Melnyk, Steven A.; Gonzalez, Richard F. and Anderson, Stephen T.; Manufacturing Resource Planning: Insights into a New Corporate Way of Life, unpublished manuscript prepared for the Educational and Research Foundation of APICS, March 1983.

Meyer, A. D., "Adapting to Environmental Jolts," Administrative Science Quarterly, Vol. 27, 1982, pp. 515-537.

Moskowitz, Herbert, "The Value of Information in Aggregate Production Planning - A Behavioral Experiment," IIE Transactions, Vol. 4, No. 4, pp. 290-297, December 1972.

Nelleman, David O., "Production Planning and Master Scheduling: Management's Game Plan," APICS 22nd Annual International Conference Proceedings, APICS, 1979, pp. 166-168.

Mather, Hal, "Making it All Work," Production and Inventory Management, Third Quarter 1982, Journal of the American Production and Inventory Control Society, Vol. 23, No. 3.

Mehta, Naren, "How to Start having Production Plan Meetings," APICS 26th Annual International Conference Proceedings, APICS, November 1-3, 1983, pp. 551-555.

Muegel, A. L., "A Case Study of a Successful Planning System - Creating/Controlling the Production Plan and MPS," Master Planning Seminar Proceedings, March 1982, APICS, pp. 55-68.

Njus, John, "Resource Requirements Planning: The Sunstrand Model," APICS 26th Annual International Conference Proceedings, American Production and Inventory Control Society, November 1-4, 1983, pp. 480-483.

Orlicky, Joseph, Material Requirements Planning (New York: McGraw-Hill, 1975).

Pannesi, Ronald T. and Melnyk, Steven A., "The Role of Manufacturing in the Corporate Strategy," Operations Management Review, Vol. 2, No. 2, Winter 1984.

Pannesi, Ronald T., "Twenty Questions for the Company President to Ask in MRP Project Steering Committee Meetings," in Computer in Manufacturing: Manufacturing Resource Planning (Pennsauke, N.J.: Auerbach Publishing, November 1983), Article No. 4.2.4 S15.

Pannesi, Ronald T., "Manufacturing Resource Planning - Implications for Strategic Planning," unpublished paper delivered at the Academy of Management Annual Conference, August 1984.

Pedhazur, Elazar J., Multiple Regression in Behavioral Research, Second Edition (New York: Holt, Rinehart and Winston, 1982).

Pendleton, William E., "MRP II Begins with the Strategic Business Plan," APICS 22nd Annual International Conference Proceedings, APICS, 1980, pp. 252-255.

Phillips, Lynn W.; Chang, Dae R. and Buzzell, Robert D.; "Product Quality, Cost Position, and Business Performance: A Test of Some Key Hypotheses," Working Paper, Stanford University, Graduate School of Business, 1983.

Pittenger, Alan, "How to Improve your Master Schedule," Master Planning Seminar Proceedings, The American Production and Inventory Control Society, March 1982, pp. 1-8.

Plossl, George W., "MRP Yesterday, Today and Tomorrow," Production and Inventory Management, Third Quarter 1980, Journal of the American Production and Inventory Control Society, Vol. 21, No. 3.

Plossl, George W. and Wight, Oliver W., Material Requirements Planning by Computer, American Production and Inventory Control Society, 1971.

Porter, Michael E. and Millar, Victor E., "How Information Gives you Competitive Advantage," Harvard Business Review, July-August 1985, pp. 149-160.

Porter, Michael E., Competitive Strategy (New York: The Free Press, 1980).

Proud, John F., "Controlling the Master Schedule," Production and Inventory Management, Second Quarter 1981, Journal of the American Production and Inventory Control Society, Vol. 22. No. 2.

Raffish, Norm, "Business Planning - The Horse Before the Cart," APICS 26th Annual International Conference Proceedings, November 1-4, 1983, pp. 318-320.

Roush, Charles H. and Ball, Ben C., "Controlling the Implementation of Strategy," Managerial Planning, November/December 1980, pp. 3-12.

Scheela, William J., "Manufacturing's Role in the Strategic Planning Process: A Case Study," American Institute of Decision Sciences Proceedings, November 1982.

Schaeffer, Richard L.; Mendenhall, William and Ott, Lyman; Elementary Survey Sampling, Second Edition (North Scituate, Mass.: Duxbury Press, 1979).

Schendel, Dan E. and Hofer, Charles W., Strategic Management - A New View of Business Policy and Planning (Boston, Mass.: Little, Brown and Company, 1979).

Schroeder, Roger G.; Anderson, John C.; Hill, Arthur V.; Moropoulos, Nicholas and Saraph, Jayant; "A Study of Manufacturing Strategy and Performance in Manufacturing Firms," American Institute of Decision Sciences Proceedings, November 1982.

Schultz, Terry, "Top Management Planning for Closed Loop Systems," APICS 26th Annual International Conference Proceedings, APICS, November 1-4, 1983, pp. 338-339.

Schultz, Terry, "MRP to BRP: The Journey of the 80's," Production and Inventory Management Review, October 1981, pp. 29-32.

Simon, Julian L., Basic Research Methods in Social Science - The Art of Empirical Investigation, Second Edition (New York: Random House, 1978).

Skinner, Wickham, Manufacturing in the Corporate Strategy (New York: John Wiley & Sons, 1978).

Smith D. James, "Matching the Master Schedule to the Operating Plan," APICS 25th Annual International Conference Proceedings, APICS, 1982, pp. 332-336.

SPSS X, User's Guide, SPSS Inc. (New York: McGraw-Hill Book Company, 1983).

St. John, Ralph, "Strategic Planning - The Role and Responsibility of Production and Inventory Control," APICS 23rd Annual International Conference Proceedings, APICS, 1980, pp. 194-196.

Swoyer, H. Samual, "Production Planning/Business Planning - A Key Management Communications Link," Master Planning Seminar Proceedings, American Production and Inventory Control Society, March 1982.

Taubert, William H., "A Search Decision Rule for the Aggregate Scheduling Problem," Management Science, Vol. 14, No. 6, February 1968, pp. B343-B359.

Taylor, Paul A., "Aggregate Inventory Management - Measurement and Control," APICS 18th Annual International Conference Proceedings, APICS, 1975, pp. 433-446.

VanDierdonck, Roland, "Designing Production Planning and Control Systems," Production and Inventory Management, Fourth Quarter 1981, The Journal of the American Production and Inventory Control Society, Vol. 22, No. 4.

VanDierdonck, Roland and Miller, Jeffrey G., "Designing Production Planning Control Systems," Journal of Operations Management, Vol. 1, No. 1, American Production and Inventory Control Society, August 1980.

Visagie, Martin S., "Production Planning, It Touches Us All," APICS 24th Annual International Conference Proceedings, APICS, 1981, pp. 142-144.

Wacker, J. and Hills, F. S., "The Key to Success or Failure of MRP; Overcoming Human Resistance," Production and Inventory Management, 1977, The Journal of the American Production and Inventory Control Society, Vol. 18, No. 4, pp. 7-16.

Wemmerlov, Urban, "Design Factors in MRP Systems: A Limited Survey," Production and Inventory Management, Journal of the American Production and Inventory Control Society, Fourth Quarter 1978.

Wight, Oliver W., MRP II - Unlocking America's Productivity Potential (Boston: CBI Publishing Company, 1981).

Wight, O. W., Newsletter (Newbury, N.H.: Oliver Wight, Inc., November 1977).

Wight, Oliver W., Production and Inventory Management in the Computer Age (Boston: CBI Publishing Company, 1974).