THE IMPLEMENTATION OF MATERIAL REQUIREMENTS PLANNING (MRP) SYSTEMS IN EGYPTIAN MANUFACTURING COMPANIES: AN EMPIRICAL STUDY

BY

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TO

THE GREATEST LOVE IN MY LIFE

MY PARENTS

ABSTRACT

The new world economic conditions and increasing global competition have changed the way in which manufacturing companies view production/operations management and their role in achieving greater productivity, lower costs, operational efficiency and better customer service. Several manufacturing planning and control systems have been developed in order to enable manufacturers to meet these new challenges. Material Requirements Planning System-MRP I and its extension Manufacturing Resources Planning System-MRP II, the much proclaimed systems, have gained wide acceptance from both academics and practitioners.

The research presented here concentrates on the key issues of MRP practices and the effectiveness of MRP systems. Evidence from the literature shows that over 60 percent of MRP I/MRP II users have failed to achieve the expected benefits. Also, a review of the literature reveals that very little work has been done to provide mathematical models to relate these benefits to their determinants. Furthermore, it reveals that much was written about MRP practices based on case studies, but very few studies survey-based have been conducted to investigate MRP implementation. None of these studies was conducted in less developed countries.

The researcher has attempted to fill some of these gaps in this study by posing three key questions, namely: how have MRP systems been implemented in Egyptian manufacturing companies?, what are the benefits obtained from these which have been implemented?, and what are the explanatory variables of MRP systems effectiveness?.

Accordingly, the objectives of the current study are threefold:

- To investigate MRP practices in Egyptian manufacturing companies.
- To assess the effectiveness of MRP practices measured by the benefits obtained from MRP implementation based on the expectations and perceptions of MRP users in Egyptian manufacturing companies.
- To explore and examine the explanatory variables of MRP systems effectiveness.

This study has drawn on an extensive review of the literature and previous empirical studies in western industrialised countries and in newly industrialised countries.

The strategy used to achieve the research objectives involved quantitative analysis of questionnaire data. Data for the study were collected by a postal questionnaire. One questionnaire was sent out to each company within the Egyptian industrial ex-public

sector. Companies were asked if an MRP user in their organisations could respond (production manager or materials manager or inventory control manager or master scheduler or management information systems manager). Of 200 questionnaires sent out, 123 replies were received, giving a response rate of 61.5%. Of the 123 replies, 93 respondents were usable giving a usable response rate of 46.5%: some unusable responses were the result of a high proportion of missing values. The final usable sample was broken-down into respondents from companies which had implemented MRP systems and respondents from non-MRP companies (52:41).

Extensive quantitative methods to analyse questionnaire data were used i.e. Frequency Analysis, Mean Value, Standard Deviation, Mann-Whitney test, T-test, Kruskal Wallis, One Way Analysis of Variance (ANOVA), Paired T-test, Spearman's Correlation Coefficient, Bartlett's test, K-M-O technique, Principal Component of Factor Analysis, Eigenvalue criterion, Varimax Rotation technique, Skewness method, Cook's Distance measure, Scatterplots method, Adjusted R^2, OLS technique, Forward and Backward Stepwise strategies and ACE model (Alternating Conditional Expectation technique).

This study has provided important insights into the current situation and practices related to MRP users in Egypt. The main findings of this study indicated that MRP practices in Egypt are relatively similar to those in the newly industrialised countries and in the west.

The findings of this research indicated that Egyptian users believe that the expected benefits from MRP implementation have been obtained, though most of the companies which have installed MRP are relative beginners. However, not all MRP users attained the same degree of MRP benefits.

Our findings indicated that the MRP benefit-determinant relationships take a non-linear form for several relationships. Knowledge of this non-linearity may be advantageous for both MRP managers and users in order to manage these relationships effectively for achieving the effectiveness of MRP practices.

Finally, valuable implications have been drawn for managers and practitioners to achieve more successful implementation of MRP systems.

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CHAPTER ONE

Introduction to the Study

1.1 Introduction

This research aims to investigate the state of practice of MRP[1] systems in Egyptian manufacturing companies, to assess the effectiveness of MRP practices measured by the benefits obtained from MRP implementation, and to explore & examine a set of the explanatory variables of MRP systems effectiveness i.e. uncertainty, organisational, implementational, technological, and human determinant variables in Egyptian manufacturing companies.

To do that, a model framework including both the explanatory variables and MRP benefits is suggested, current MRP practices in Egypt are investigated, testing if significant differences exist among MRP users regarding the benefits obtained from MRP implementation, then regression models to relate the key determinant variables (independent) to MRP implementation benefits (dependent variables) are developed.

The main objective of this chapter is to acquaint the reader with the general outlook of the study. So, the second section identifies the rationale of the study, the third section states the problems of this study, the fourth section delineates the major tasks of the current study, the fifth section states its significance, the sixth section provides the

[1] The term "MRP" is used in this study to include all versions of MRP systems (i.e. Material Requirements Planning (MRP I), Closed-loop MRP, and Manufacturing Resource Planning (MRP II)) because the only concern here is with the implementational issues in terms of the state of practice of MRP systems and its effectiveness as in Schroeder et al. (1981); Duchessi et al. (1988); Cooper and Zmud (1989;1990); Turbide (1990); Ptak (1991); Sandeep (1992); Vollmann et al. (1992); Dilworth (1993); Sum and Yang (1993); Sum et al. (1995) and Browne et al. (1996).

main contribution of the study, the seventh section specifies its scope, the eighth section states the structure of the thesis and the last section provides a summary of this chapter.

1.2 Rationale of the study

Many factors characterise today's manufacturing environment such as: increased product variety, intensifying global competition, changing social expectations and rapid advancement of manufacturing technology (Ang et al., 1995; Browne et al., 1996; Carrie et al., 1997).

Accordingly, manufacturing companies find themselves in a totally changed environment, so they must improve both their products and their productivity, and which means making their manufacturing processes more efficient and effective to remain competitive.

An important factor for improving these processes is production control (Cooper and Zmud, 1989). A variety of information systems to support production control such as Material Requirements Planning (MRP I) & Manufacturing Resources Planning (MRP II), Just -in-Time (JIT) and Optimised Production Technology (OPT) have been developed to replace the traditional reorder point-based information systems.

Materials Requirements Planning (MRP I) and its extension Manufacturing Resources Planning (MRP II), have both gained the acceptance from academics and practitioners as important factors for improving manufacturing processes (Goh, 1984; Aggarwal, 1985; Cooper and Zmud, 1989; Sandeep, 1992; Newman & Sridharan, 1992; Turbide, 1995; Browne et al., 1996; Robertson et al., 1996; Lunn, 1996; John and Charlotte, 1996; Carrie et al., 1997).

However, there is a reported dissatisfaction with MRP/MRP II use by the implementers. Duchessi et al. (1989) reported that there have been numerous failures in implementing MRP/MRP II, with consequent financial loses and disruption of operations. Furthermore, Aggarwal (1985); Fintech (1989); Sandeep (1992) and Hill (1993), reported that despite the huge investments in MRP systems, over 60 percent of MRP/MRP II users have failed to achieve the expected benefits. In the same way, Browne et al. stated:

> "Only a very small percentage of users of MRP consider themselves to be successfully operating their MRP systems. Many systems are installed, as opposed to implemented, i.e. the formal system is not the real system" (1996, P.188).

Also, the literature review reveals that there are numerous studies that have dealt with various aspects of MRP implementation. However, very few studies have been done to assess the effectiveness of MRP practices measured by the benefits obtained from the implementation of MRP systems within manufacturing companies (Schroeder et al., 1981; White et al., 1984; Anderson and Schroeder, 1984; Sum and Yang, 1993). Besides, very little work has been done to specify and measure all possible explanatory variables of MRP systems effectiveness (Duchessi et al., 1988; Sum et al., 1995).

However, most of these studies are based upon case studies or personal experience, namely empirical studies on MRP practices have been limited (Duchessi et al., 1989; Sum and Yang, 1993; Ang et al., 1995). The problem with case studies is that the failures are rarely documented because the authors are typically employees of (or consultants to) the companies described in the cases (Burns et al., 1991), as such the lessons may not be applicable in other cases (Ang et al., 1995).

The literature review reveals that previous studies were conducted either in developed countries such as the US (Schroeder et al, 1981; White et al., 1984; Anderson and Schroeder, 1984; Duchessi et al., 1988;1989) or in the newly industrialised countries such as Singapore (Sum and Yang, 1993; Ang et al., 1995; Sum et al., 1995).

A new era of transformation process in Egypt is the core for its economic reform-transformation from losing to winning companies. This transformation increases the importance of the function of production management, where the future holds enormous opportunities and challenges for production management. Furthermore, at national level, Egypt faces increasing regional and international competition, while at operational level, in most manufacturing companies the following statements sound familiar: "we have got too much inventory... we are not as a competitive as we used to be... we are losing market share". In most cases this stems from manufacturing companies not making the right things at the right time. In response, manufacturing companies should make their processes more efficient and effective. To do so, many manufacturing companies in Egypt have implemented, are implementing or are considering the implementation of MRP systems.

However, as pointed out by Per-lind (1991), Egyptian manufacturing companies which have decided to acquire new technology such as MRP systems have had limited success in implementing it. For instance, he mentioned that 70% of all installed computers can be regarded as not optimally utilised. Also, he claimed that it is not unusual to have an effective utilisation of 5-10 percent and it has even happened that computers are unused for two and three years.

Accordingly, this study aims to fill some of the gap relating to the scarcity of empirical studies concerning MRP practices; the effectiveness of MRP implementation measured by the benefits obtained from MRP practices is assessed, and also the MRP benefit-determinant relationships are explored and examined. This is based upon the data collected from MRP users within the manufacturing sector of Egypt.

1.3 Statement of research problems

Taking into account the above discussion, the main conclusion has been that in spite of the fact that empirical studies regarding the state of practice of MRP systems permit managers, current users, potential users, and vendors of MRP systems to obtain a better understanding of the implementation of MRP systems and allow researchers to proceed with the task of developing and testing theories of MRP implementation, the literature review reveals that studies which have been done to investigate MRP practices based upon survey are relatively few compared to those conducted on a case study base whether in developed countries such as the US or in the newly industrialising countries such as Singapore.

In spite of the growing popularity of MRP systems, no study has been conducted which provides empirical evidence to monitor the state of MRP practices in Egypt.

Despite the fact that a very small percentage of users of MRP consider themselves to be successfully operating their MRP systems, there is a scarcity of empirical evidence that assesses the effectiveness of MRP practices measured by the benefits obtained from the implementation of MRP systems within manufacturing companies.

In spite of the fact that studies concerned with specification and measurement of all the possible explanatory variables of MRP systems effectiveness may help both MRP managers and users to focus on key areas to achieve the expected potential benefits that match their companies goals and to improve the efficiency of MRP implementation and allow researchers to examine certain hypotheses regarding MRP practices, no study has been conducted which provides empirical evidence about the correlation of all of the following factors (i.e. uncertainty, organisational, implementational, technological, and human factors) with the benefits obtained from MRP implementation.

Even though there is a growing volume of literature on the implementation of MRP systems in developed countries and the newly industrialising countries, no comprehensive and systematic research has been done to investigate the state of practice of MRP systems, its effectiveness measured by the benefits attained, and to specify and measure all the possible explanatory variables of such effectiveness in one study.

Accordingly, there are three questions that need to be investigated concerning MRP implementation in Egyptian manufacturing companies:

- *How have MRP systems been implemented?,*
- *what are the benefits obtained from these which have been implemented, and*
- *What are the explanatory variables of MRP systems effectiveness?.*

1.4 Tasks of the study

Correspondingly, to reply to the previous mentioned questions the tasks of this study were evolved as follows:

1.4.1 A conceptual model

To suggest a conceptual model which provides a greater understanding of the issue under investigation and to develop a theoretical model framework concerning the key determinant variables of MRP benefits.

1.4.2 The state of MRP practices

To detect and outline the state of practice of MRP implementation which can be accomplished by covering several key issues, such as: MRP company profile (i.e. size and age, type of manufacturing system, type of manufacturing process and layout), MRP systems characteristics (i.e. hardware and software, degree of computerisation, degree of integration, system features, MRP definitions), the stage of MRP implementation (i.e. user class), initiators of MRP (i.e. those who introduce MRP to the company e.g., top management, production managers, vendors etc.), MRP implementation problems, MRP systems growth, factors that may impede non-users to implement MRP systems and finally the main areas for promoting MRP systems based on points of view of MRP users within the Egyptian manufacturing companies.

1.4.3 MRP systems effectiveness

To assess the effectiveness of MRP practices measured by the benefits obtained from MRP implementation based on the expectations and perceptions of MRP users and to explore and examine the MRP benefit-determinant relationships in Egyptian manufacturing companies.

1.5 Significance of the study

Accordingly, the importance of this research was drawn at various levels as we will mention below:

1.5.1 Personal level

(1) To the best of the researcher's knowledge, this is the first study to address the issue of MRP practices and its effectiveness measured by the benefits obtained from MRP implementation in a less developed country. It adds to this issue by investigating the impact of a set of uncertainty, organisational, implementational, technological, and human factors on the effectiveness of MRP implementation measured by the benefits obtained by the Egyptian users, and this can be claimed to be one of its main aims of significance.

1.5.2 Theoretical level

(1) A conceptual model was developed in this study to outline the successive stages should be taken into account for investigating the state of MRP practices and its effectiveness. The study considered the extent to which uncertainty, organisational, implementational, technological, and human factors affect this effectiveness.

(2) It is hoped that the body of the literature will contribute in providing useful information which may help in filling the gap of the literature review relating to the critical factors that influence MRP implementation.

1.5.3 Empirical level

(1) Even though the empirical results concerning the MRP benefit-determinant relationships developed by Sum et al. (1995) are encouraging, the authors still call for a great deal of further research to be done. Replications of their work are needed to corroborate the results. This research attempts to do that. While the previous study only investigated the relationships between a set of organisational, technological and implementational variables and MRP benefits, this research has extended these variables to include the uncertainty and human variables.

(2) It is the first empirical study that tests to what extent the implementation of MRP systems is affected by the uncertainty factors.

1.5.4 National level

(1) As far as the researcher is aware, this research reports on the first extensive study on the state of practice of MRP systems in less developed countries in general, and in Egypt in particular.

(2) It is expected that the government policy makers and other MRP promoters in Egyptian industrial sector can take advantage of the empirical results of this study to formulate the relevant strategies and programs to sustain the Egyptian manufacturing sector to increase their use of MRP systems.

1.5.5 Methodological level

(1) It develops a series of mathematical models using the Alternating Conditional Expectation (ACE) method as an advanced statistical technique that increases the model fit by approximating the optimal transformations for the dependent variables (MRP

benefits) and independent variables (uncertainty, organisational, implementational, technological and human factors).

1.6 Contribution to current knowledge

This study contributes to what is currently a very limited amount of empirical research (survey) on MRP implementation. And also, it contributes to what is currently a limited amount of empirical evidence to explore and investigate all the possible explanatory variables for MRP systems effectiveness. As a contribution to the academic work, the current study develops a conceptual model which may help to investigate these issues.

Furthermore, this study uses a novel method (ACE technique) to investigate the benefit-determinant relationships in implementing MRP, providing valuable insights for managers and practitioners hoping to achieve successful implementation of MRP systems.

1.7 Scope of the study

The current study based upon points of view of MRP users (i.e. the production managers, materials managers, inventory control managers, master scheduler and management information system managers) has attempted to provide better understanding of the state of practice of MRP systems and which may help to judge its effectiveness in less developed countries. Within this prospective the scope of this research is empirical, descriptive and an analytical interpretative as shown in detail below:

1.7.1 Empirical

The empirical characteristic of this study is derived from its main objectives, that is the methodical and systematic investigation to detect and outline the state of MRP practices, to assess its effectiveness and to explore and examine the possible explanatory variables of MRP systems effectiveness in Egyptian manufacturing companies.

1.7.2 Descriptive

Also, this study is descriptive because it has relied on an extensive literature review for developing a model framework with respect to the determinant variables of the benefits obtained from MRP implementation.

1.7.3 Analytical-interpretative

Finally, it is an analytical-interpretative study for making a comparison between the preceding studies which were applied in developed countries or the newly industrialised countries concerning the implementation of MRP systems and the data which are generated by this study.

1.8 Organisation of the dissertation

Following this introduction, # Chapter two (Literature review) investigates the appropriate literature, discusses the new environment challenges for manufacturing, the role of manufacturing planning and control system for helping manufacturing companies to face these challenges, highlighting its responses to forces for change reflected in providing new production management systems such as MRP, JIT and OPT systems, and the nature of the implementation of MRP systems (concepts, motivations, and evolution). It presents a major emphasis on the benefits obtained from MRP implementation, a set of uncertainty, organisational, implementational, technological, and human determinant variables affecting MRP implementation and the benefits obtained from such implementation and finally shows a suggested conceptual model which has been employed to fulfil the objectives of the study.

Chapter three (The manufacturing sector of Egypt) is designed to acquaint the reader about the main features and performance of the Egyptian industrial sector.

Chapter four (Research methodology) provides the research methodology designed to investigate the major objectives of the current research through describing the steps that are used in carrying it out. These steps are designed as a bridge between the theoretical framework and the empirical findings.

Chapter five (Data analysis: Current MRP practices in Egypt) is devoted to presenting a discussion of the field research findings related to investigating the state of practice of MRP systems.

Chapter six (Data analysis: The benefits obtained from MRP implementation and the costs spent on MRP installation) is devoted to presenting a discussion of the field research findings related to investigating the tangible and subjective benefits obtained from MRP implementation, in addition to the costs spent on MRP installation.

Chapter seven (Data analysis: The MRP benefit-determinant relationships) is devoted to presenting a discussion of the field research findings related to investigating the relationship between the uncertainty, organisational, implementational, technological, and human determinant variables and the benefits obtained from MRP implementation.

Chapter eight (Conclusions and recommendations for further research) gives a summary of the main findings of the study, shows main implications of the study, presents the theoretical contributions to the literature in general and the empirical contributions to MRP managers and users in the Egyptian industrial sector in particular, states limitations of the study and finally suggests a number of proposals are as a springboard for further research.

1.9 Summary

Having conducted a thorough search in the literature, areas lacking research efforts are identified. The current study proposes a model framework and mathematical models to relate the benefits obtained from MRP implementation and the determinant variables that influence them. Moreover, it presents a useful comparative data for academics. In addition, as a contribution to the practitioners, the study provides summary statistics of the state of practice of MRP systems in Egypt, and also highlights the determinant variables of MRP implementation benefits.

CHAPTER TWO

MRP Systems Implementation

Review of Related Literature and Research

2.1 Introduction

The aim of this chapter is threefold. It aims first to outline the main characteristics of the new business environment facing industrial companies. Second, it briefly presents the significance of manufacturing planning and control system within manufacturing companies. Lastly, it provides information on the state of practice of an MRP system and its effectiveness highlighting the expected potential benefits and the actual benefits obtained from MRP and the critical factors that influence MRP suitability and success of MRP implementation as in Duchessi et al. (1988); Sum and Yang (1993) and Sum et al. (1995).

The second section of this chapter presents an introduction to the subject of the new environment challenges for manufacturing. The third section begins with the significance of manufacturing planning and control system, the general framework of it, its role, and concludes with MPC responses to forces for change highlighting the most popular new production management systems that have been implemented by manufacturing companies in order to satisfy the new needs of business. The fourth section shows how MRP systems are still number one regarding their widespread implementation. The fifth section presents the evolution of MRP systems. The sixth section gives a general notion about the MRP systems in such a manner that clarifies the state of practice of MRP systems, presenting the main barriers that impede the implementation of MRP systems by non-users and the main areas for promoting MRP systems. The seventh section shows the effectiveness of MRP practices highlighting the expected potential benefits and the actual benefits obtained from MRP implementation (tangible benefits -improved performance and intangible benefits-users satisfaction), and concludes with indicating the key failings of MRP systems. The eighth section presents the critical factors that influence MRP suitability and success of MRP implementation. The last section presents an extensive summary of the issue under investigation followed by presenting the gaps need to be empirically investigated by undertaking the current study, then illustrating a conceptual model framework which might provide a greater understanding of the subject matter and a suggested model framework of the explanatory variables of MRP effectiveness.

2.2 The new environment challenges for manufacturing

There are many factors that may have a fundamental impact on today's manufacturing environment these include: improved IT capabilities, new production management approaches, increased product variety, changing manufacturing costs patterns, changing social expectations, rapid growth of processes and materials and increasing the need to respond rapidly to customer requirements (Maly, 1988; Chamberlain and Thomas, 1995; Ang et al., 1995; Strzelczak, 1995; Browne et al., 1996; Titone, 1996; Carrie et al., 1997).

Jewitt (1995) has pointed out that throughout the 90s, manufacturing industry will be asked to reply to an augmenting set of threats and opportunities, for instance, the need to prove that products and processes are environmentally-friendly will be derived from customer and demand, the advance of technology will continue to affect products and the manufacturing process, relationships with supplier will be very significant, and the competition will increase.

This dramatic change in the business environment led to increasing "manufacturing dilemma" and which has been reflected in two main problems: the first, is the variety and great complexity of products, materials, technology, machines, and people skills (Plossl, 1995), and the second, is increasing the uncertainty as a result of unpredictable behaviour of customers and suppliers outside the business and unreliability of behaviour of people and plant within the company (Puttick, 1987).

Accordingly, manufacturing companies struggle to cope with this changed environment, through improving both their products and their productivity or optimise their uses of tools and resources. This means making their processes more efficient and effective to remain competitive as a matter of survival.

Putterill et al. (1996) concluded that manufacturing companies need to improve their manufacturing operations in order to achieve the required improvements in business performance. This has been frequently attained through adopting Computer Aided Production Management - CAPM such as MRP systems (Corke, 1985; Sandeep, 1992; Carrie et al., 1997) which hold the promise for significant improvements in everything from quality to cost, quantity, delivery, speed and accuracy. One of the most important functional areas of the application of CAPM is manufacturing planning and control area (Paul and Suresh, 1991; Gerwin and Kolodny, 1992).

Hence, the next section (2.3) is devoted to discuss briefly the importance of manufacturing planning and control systems that may enable manufacturing companies to match changes of their business, followed by the discussion and the presentation of the most popular manufacturing planning and control systems in last three decades.

2.3 Manufacturing planning & control system (MPC)

The previous section revealed that there are several changes and needs challenging manufacturing companies. Under modern manufacturing pressures, manufacturing planning and control systems are required together with clearly defined objectives, rules, and the like in order to enable manufacturing companies to achieve their goals quickly and comprehensively or to trace the developments in business environment (Paul and Suresh, 1991). Therefore, it is interesting to determine the importance of MPC, its functions, its activities, and to present its developments in order to confront changes of business from time to time. These are viewed below:

2.3.1 The significance of MPC system

Vollmann et al. (1992) defined manufacturing planning and control system as a source of information to effectively manage the flow of materials, effectively utilise people and equipment, co-ordinate internal activities with those of suppliers, and communicate with customers about market requirements.

Likewise, Hill stated that production planning and control is "the development of schedules to achieve timely delivery of finished products. It requires a knowledge of each component, of time estimates for each process, and the capacity (usually in hours) of each machine or work centre. This knowledge is essential since schedules list when each component should be processed on each work centre so that the product can be assembled and delivered on time, and meet sales and distribution targets" (1994, p.127).

More significantly, Vollmann et al. (1992) pointed out that several management activities are supported by MPC system, some of them are: plan capacity requirements and readiness to meet marketplace needs, plan to assure that the required materials will arrive on time in the right quantities, maintain appropriate inventories of raw materials, work in process, and finished goods in the right locations, schedule production activities so people and equipment are working on the correct things, track material, people, customers' orders, equipment, and other resources in the factory, meet customer requirements in a dynamic environment, and provide information to other functions on the physical and financial implications of the manufacturing activities.

In the broadest sense, the goal of MPC system is to support the strategy and tactics pursued by the company in which they are implemented.

2.3.2 MPC system framework

If manufacturing companies aim to carry out MPC system activities in accordance with their marketplace's requirements (and this may be different from one company to another or from time to time for the same company) it is both interesting and helpful to show a general framework model of manufacturing planning and control (MPC) system which has been suggested by Vollmann et al. (1992). They classified the activities of the MPC system framework into three groups of activities namely, the front, the engine and backend activities.

(1) The front activities represent the planning and preparation activities. Demand management represents forecasting, order promising and other activities that place demand requirements on manufacturing capacities. These demand requirements are evaluated for resources and translated into workable Master Production Schedule. The MPS is the disaggregated version of the production plan, which provides the production input to the company game plan and determines the manufacturing role in this agreed-upon strategic plan. Resource planning provides the basis for managing the match between manufacturing plans and capacity.

(2) The engine activities are the central mechanism for MPC. It is concerned with the detailed material planning which directly depends upon the master production schedule. This material plan can be utilised in the detailed capacity planning to compute labour or machine centre capacity required to manufacture all the component parts. These plans are the specific guides for implementation in the backend- the supplier and the production line.

(3) The backend activities represent the execution activities which often end with the measurement of actual results. These three phases for manufacturing planning and control are depicted in Figure 2.1 below:

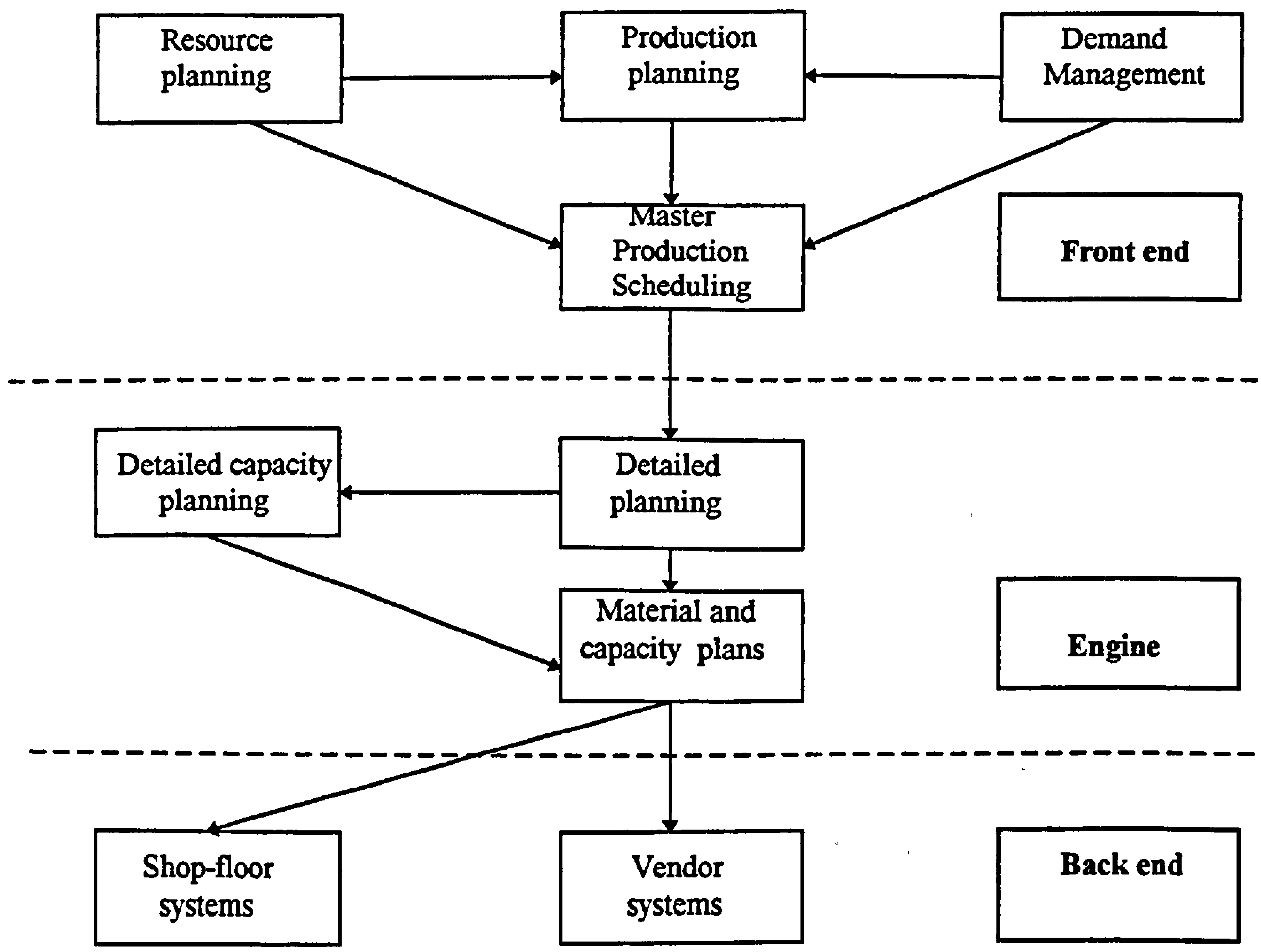

Figure 2. 1 Manufacturing Planning and Control system (Quoted from Vollmann et al., 1992: P.5).

It is worth mentioning here that it is not necessarily that all of these activities must accomplished in any manufacturing company, but there must be at least front-end, engine, and back-end activities.

2.3.3 The role of MPC system

Plossl (1995) has confirmed the above significant role of MPC by saying that there are three functions of manufacturing planning and control:

- Developing a sound game plan. This requires two sets of numbers: first, a Production Plan (long term) and, second, Master Production Schedules (short term).

- Offering an adequate capacity needed to support the game plan.
- Helping to correct priorities by producing the right things at the right time in the required quantities.

Furthermore, he said that there are six questions representing a universal logic that underlies all manufacturing, they are: What is to be made?, How many, and when are they needed?, What resources are required to do this?, Which are already available?, Which others will be available in time?, and What more will be needed, and when?.

The first two questions are answered by business and marketing strategies. But the answers for last four questions are provided by manufacturing planning control systems. More specifically, the significant relationship between manufacturing planning and control system and strategic and business planning is illustrated in Figure 2.2 below:

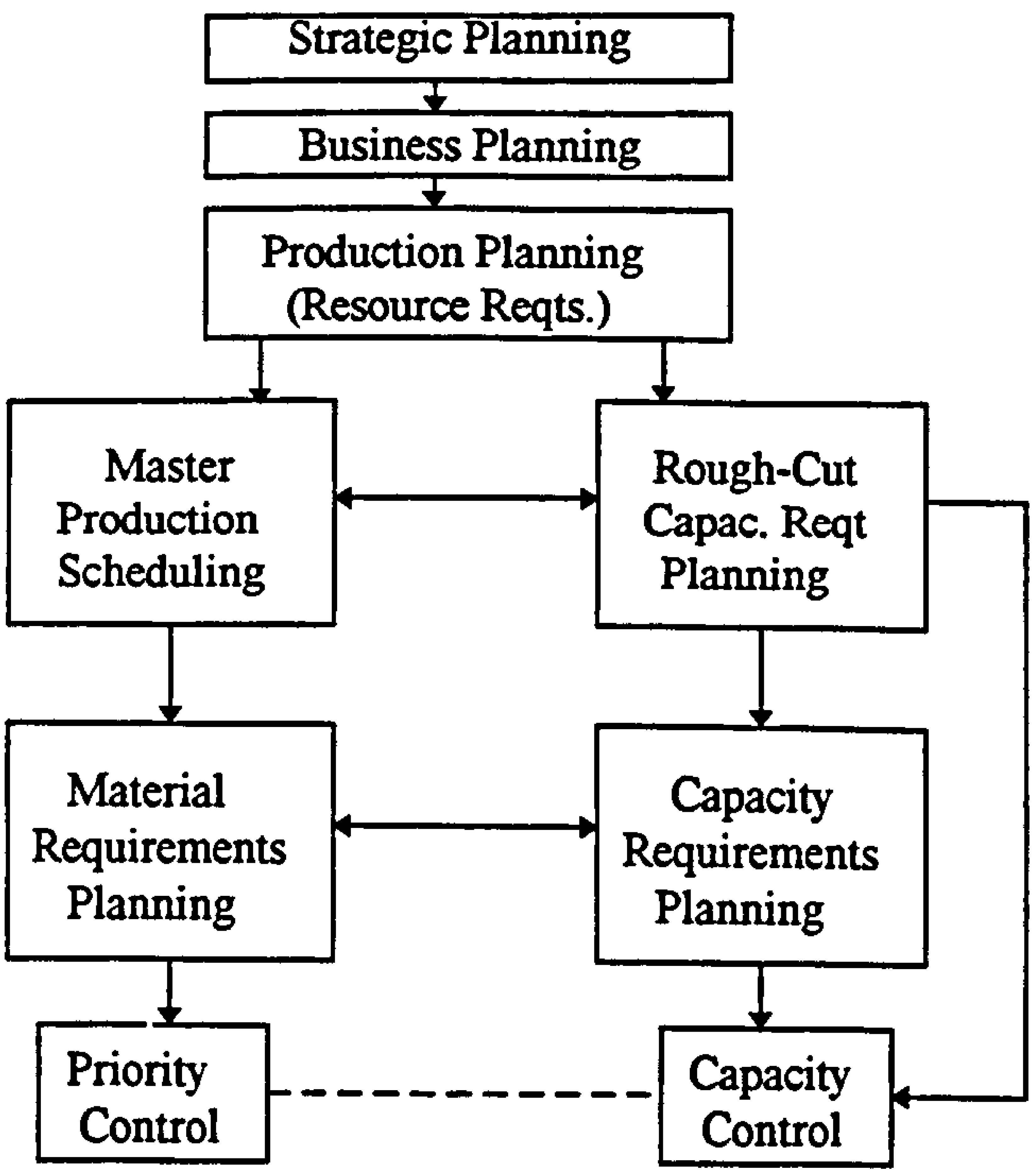

Figure 2. 2 The core system (Adopted from Plossl, 1995: P.2).

Figure 2.2 reveals the core system linking strategic, business and production planning. Strategic plans cover long horizons and include strategies for type of products and the marketplaces entered. Business plans have a shorter horizon concentrate on product families to meet strategic goals, and define the market the company serves (Goh, 1984). Production plans are more detailed than strategic and business plans and cover manufacturing facilities needed to support both strategic and business plans and they specify the quantities of products and amounts of resources which include capital, employment and skills, plant and equipment. Plossl added the structure of the core planning system integrates five basic elements utilising techniques common to all manufacturing:

1. Master production schedule (MPS)- which is used to develop the data showing which products must be produced, how many, and when. These data are restricted by the strategic, business, and production plans and drive all detailed operating plans.

2. Material requirements planning (MRP)- which determines the quantities of materials needed to support the MPS and when they should be scheduled.

3. Capacity requirements planning (CRP), which helps evaluate the resources (people, machines, etc.) needed to support the MPS and Rough-Cut- Capacity Planning (RCCP) which involves a quick check on a few key resources required to implement the MPS in order to ensure that it is feasible from a capacity viewpoint (Browne et al., 1996).

4. Production activity control (PAC)- which is used to evaluate the performance in the material/priority execution phase, by comparing it to plans.

5. Input and output capacity control (I/O)- whereas the actual capacities are compared to plans and signals sent for actions needed.

2.3.4 MPC system responses to forces for change

As pointed out in section 2.2 the business environment is continuously changing. Therefore, manufacturing companies should adjust their strategies as a reaction to these developing needs. In response to these changes and needs, the development of new paradigms, principles and expectations for industrial management was originated on an equal footing (Strzelczak, 1995). Consequently, several approaches to production planning and control such as Material Requirements Planning and Manufacturing Resources Planning(MRP I/ MRP II), Just-in-Time (JIT), and Optimised Production Technology (OPT) systems have been developed and publicised over the past three decades. Figure 2.3 shows typical MPC responses to forces for change below:

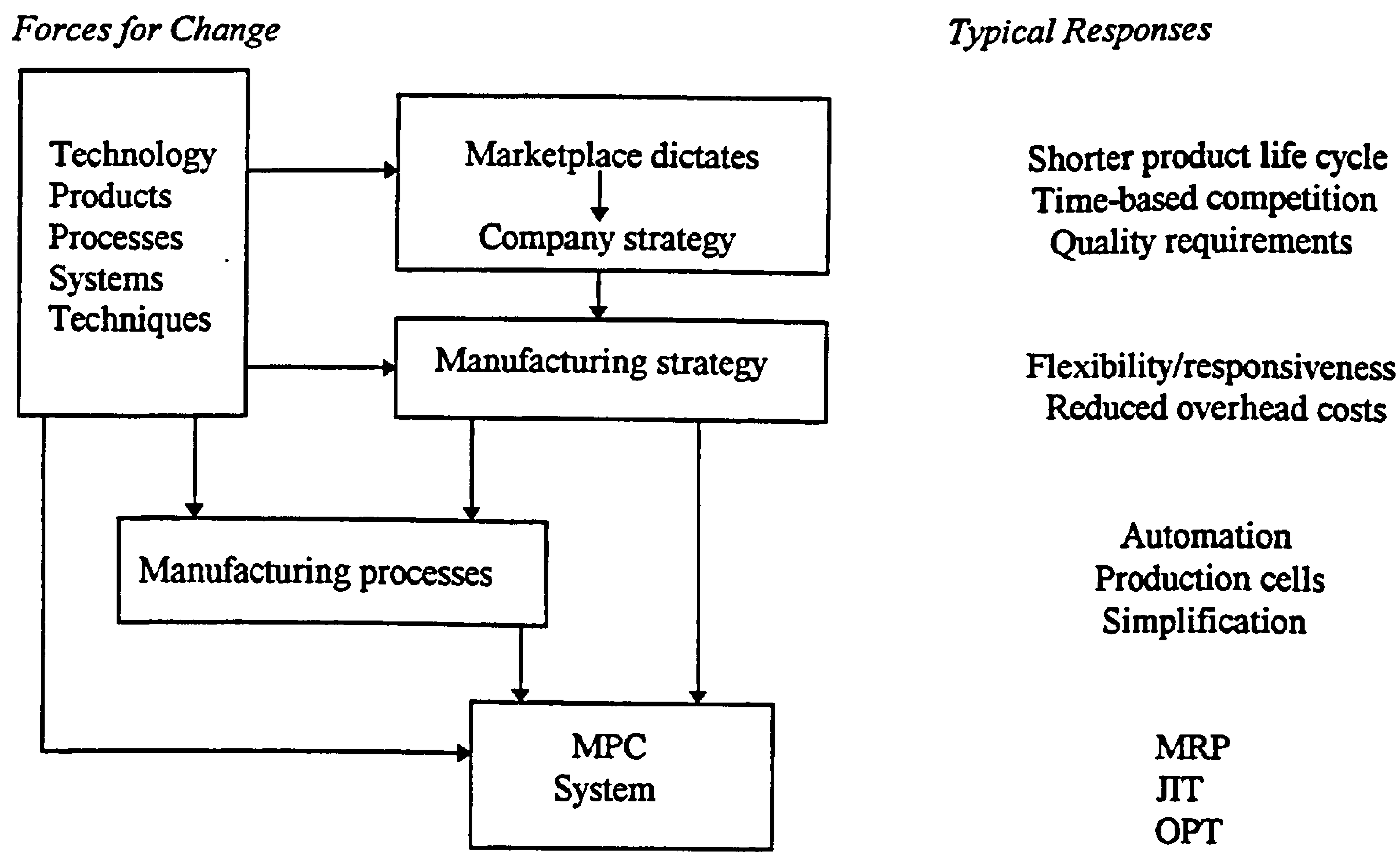

Figure 2. 3 Evolutionary responses to forces for change (Adopted from Vollmann et al., 1992: P.10).

Figure 2.3 indicates that manufacturing companies should change their strategies to respond changes in marketplace, which in turn often call for changes in manufacturing strategy, manufacturing processes, and MPC systems. The main implication can be extracted from Figure 2.3 that MPC system should be evolved to meet changing requirements in the market, products and manufacturing processes in harmony with the company's game plan.

This confirms that MPC is a dynamic field that will continue to evolve from time to time in order to fulfil manufacturing companies needs for instance offering advanced and quality products, fulfilment of customer needs and faster delivery times (Manthou et al., 1996). Therefore, the next subsections are intended to shed some light on new developments for manufacturing planning and control (MPC) systems that comes from nearly all of the field studies, to understand the difference among them, and to present to what extent manufacturing company may find itself in trouble for deciding in which system it will select in order to match its business needs.

In summary, there is some consensus among researchers within the operations management area such as Aggarwal (1985); Ptak (1991); Giauque & Sawaya (1992); Newman & Sridharan (1992); Vollman et al. (1992) and Browne et al. (1996), that Requirements Planning Systems (Materials Requirements Planning-MRP I and Manufacturing Resources Planning-MRP II), Just-in-time (JIT) and Optimised Production Technology (OPT) have been considered as the most common systems that have invaded operations planning and control in quick succession one after the other.

These systems can ease the work-load of planning and control, enable new schedules to be quickly calculated, and Work-In-Process to be decreased (Hill, 1994).

2.3.4.1 Requirements and Resources Planning Systems (MRP I/MRP II)

MRP originated in the early 1960s in the United States as a computerised approach to the planning of materials and production by manufacturing "gurus" such as Orlicky, Plossl and Wight. This system was based on some insights into production planning that were different from prevailing thought at that time. MRP developed the concept of dependent demand for components and subassemblies to plan production and reduce inventories, while the accepted concepts were on the Economic Order Quantities (EOQ) and other mathematical tools (Wight, 1981).

In studying MRP systems, one can discern easily that there are three levels for MRP definitions. MRP can be defined generally as primarily computerised materials/production planning and control systems integrated with other business areas to achieve a total business system. It can be defined in narrow sense as a computerised materials/production planning and control system for production only (Sum and Yang, 1993).

In general terms, MRP is essentially a "push system" or "order launching system" which is designed to push materials and work in progress (WIP) according to master plan by work orders (Dibono, 1997) or which transforms a master schedule of end products into parts requirements (Sandeep, 1992). But it has to be supplemented by "pull" systems or expediting in order to get orders completed when they are needed (Plossl, 1995).

2.3.4.1.1 Goals and significance of MRP systems

The overall objectives of MRP system are the reduction of inventory investments, the improvement of work flow, the reduction of shortages of materials and components, and the achievement of more reliable delivery schedules.

According to Aggarwal (1985) the goal of materials requirements planning (MRP) is to raise service and response to customers while reducing inventory investment. This system helps purchasing and production departments to move the right amount of materials at the right time to production-distribution stages and enables managers to track orders through the whole manufacturing process.

Sum and Yang (1993) reported in their study regarding MRP practices on 128 companies in Singapore that the main reasons for the implementation of MRP system were: inventory control, production control, improved productivity, lower inventory cost, improved competitive position, improved quality of products, increased throughput, and to meet delivery dates better.

All in all, Lockyer et al. (1989); Schroeder (1993); Dilworth (1993) and Krajewski & Ritzman (1996), argue that Material Requirements Planning - MRP I is still one of the popular methods of production control used by manufacturing companies.

In direct contrast, Burbidge (1989) believed that MRP was fundamentally a poor solution to the production control problem. By adopting Group Technology -GT i.e. the analysis and comparison of items to group them together and standardise them into families with similar design characteristics and requiring similar machine operations, organisations could divide one large production control problem into a series of similar, more manageable problems with each group becoming almost independent of the others. He therefore advocated a combination of GT and period batch control (PBC). The key to using GT successfully is the ability to identify readily items within the same family (Lockyer et al., 1989).

A review of the literature reveals that the benefits usually claimed for GT are reduction in the production planning time for jobs, a reduction in materials handling and in- process inventory because most of the families goes through a common sequence of nearby work stations, an increase in coordination of jobs because many of the operations can be followed visually, and also a reduction in setup time and the investment needed for holding fixtures and other tooling (Burbidge, 1989; Lockyer et al., 1989; Dilworth, 1993).

2.3.4.1.2 Assumptions and requirements of MRP systems

Ptak (1991) has pointed out that MRP requires that individual lead times are fixed and known, processes independence of manufactured items, and all components of an assembly are needed at the time of the assembly order release.

Related to the MRP prerequisites Plossl (1995) added that MRP needs support from other subsystems, including: customer order processing, process information, open manufacturing order tracking, open purchase order tracking, inventory transaction handling, and production reporting.

MRP assumes that every worker, whether operator, quality inspector, planner, salesman, analyst, or purchasing agent is strictly trained about feeding up dates into the system. Without such adherence, the memory of MRP system starts to accumulate errors concerning inventory in stock, quantities needed, and when items are needed. And also, everyone dealing with the MRP system have to make all their decisions based on the data offered by the system at every step (Aggarwal, 1985). Furthermore, it assumes that the lead time is determined in advance of the schedule and is independent of the batch size (Browne et al., 1996).

Guide and Ghiselli (1995) reported that before implementing any MPC such as MRP, JIT, and OPT, three basic elements must be in place: an inventory control system, bills of material, and accurate routings for parts/components.

Sandeep stated that MRP systems are based on three main assumptions to derive orders:

- "The master production schedule is realistic and stable. Unrealistic and unstable schedules will lead to a mismatch between demand and production.
- The lead time for each part number is usually fixed and independent of the lot size and any external influences such as shop load, production route etc..
- The manufacturing capacity is infinite during the order generation process. Consequently, it ignores the total work load on individual work centres i.e. it assumes that what is scheduled will be produced on time" (1992, p.26).

In general terms, there are several assumptions made in MRP- based planning and control programs. Some of them are explicit and the others are implicit. They are: every inventory should move into and out of stock, all components of an assembly are required at the time at which an assembly order is released, components are disbursed and used in different lots, and each manufactured item can be processed independently of any other (Plossl, 1995).

2.3.4.1.3 MRP in an MPC system framework

According to Vollmann et al. (1992) MRP represents a central issue when companies start to develop their MPC systems. Figure 2.4 shows that MRP system can work in all three areas in the general MPC system namely, the front end, the engine and the back end.

In the front end of the MPC system, MRP plays a vital role for offering the detailed planning process for components to support the MPS which represents the core of this phase of the general MPC system. In the engine section, MRP system is vital to all activities in this portion of the general MPC framework. It provides a detailed material planning, also it helps for the anticipated time-phased set of master production schedule requirements which means that the requirements will be stated on a unique period-by-period basis, rather than aggregated or averaged, and the previous data can be used as input for developing capacity plans.

Moreover, the back end section deals with shop-floor scheduling of the company and with managing materials coming from vendor and which depend to a great degree on the outputs of MRP systems.

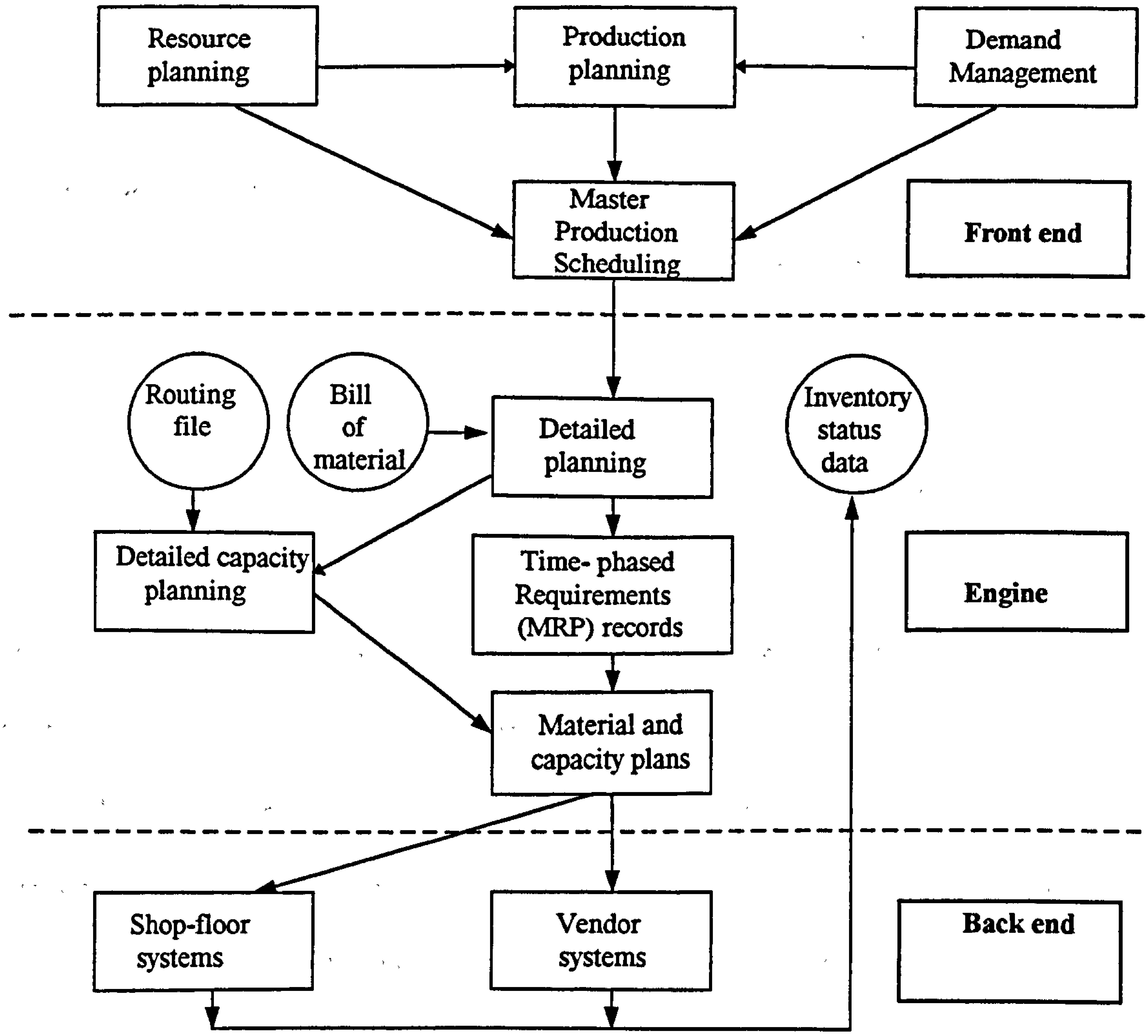

Figure 2. 4 MRP system within MPC system (Quoted from Vollman et al., 1992: P.16).

2.3.4.2 Just-in-time (JIT) system

After World War II, Japan began to surpass the United States in terms of productivity and quality. "Made In Japan" became well known in the world marketplace. This happened as a result of developing new approaches to manufacturing by Japanese companies. One of these approaches is JIT and which has its origins in the Toyota company in Japan.

In the 60s, Toyota worked on developing new approaches to manufacturing stimulated by the "oil crisis" of the 60s. By 1972 this new approach had begun to attract wide attention in Japan and in the mid 70s other Japanese companies began to experiment with and adopt them. But the approach was called the "Toyota Manufacturing System", and for some time later it was known as JIT. By the end of the 70s this system had begun to attract attention in the west.

Therefore, an attempt was conducted by several writers to clear up the term "JIT" whether in a narrow sense or in a broad sense. Matsuura et al. (1995) pointed out that JIT in a narrow sense, means an operations management system (Toyota Production System) which is featured as a mixed model assembly line fed with parts using Kanban system (sign boards) in shop floor control. In a wide sense, JIT means a manufacturing philosophy toward improving efficiency in manufacturing system through the absolute elimination of waste along with continuous improvement and workers's involvement.

Golhar et al. (1990) and Jewitt (1995), reported that the major barriers that may impede the successful implementation of JIT system may stem back from: poor knowledge about JIT, unreliable delivery schedule, failure to appreciate the importance of people for the successful implementation, lack of vendor involvement, poor training and communications, inability to manage change, changes in layout of machinery and operations, and lack of top management commitment.

2.3.4.2.1 Goals and significance of JIT

A major objective of JIT implementation is to have the right item at the right place at the right time (Dilworth, 1993), and which is same for all MPC systems. As pointed out by several writers such as Crawford and Cox (1991) and Wild (1996), the significance of JIT implementation stems back into: improving delivery and quality performance, reducing inventories and WIP, reducing space requirement, shorter throughput times, smoother work flows, improving customer service, achieving on-time delivery of a quality product therefore, market share and profit will be increased, achieving greater productivity and the reduction in process variation.

Golhar et al. (1990) reported in their study about JIT implementation in 32 small manufacturing firms (less than 500 employees) located in the midwest of the US, that the implementation of JIT led to a reduction in raw materials, work-in-process, and finished goods inventory were 80%, 58%, and 56%, respectively. Also, they reported an improvement in the quality of finished product and a decrease in the number of complaints concerning quality and delivery.

Furthermore, Sohal and Naylor (1992) have conducted a case study concerning the implementation of JIT in a small manufacturing firm in the US. The results indicate that the implementation of JIT led to achieving several benefits. Some of them are: reducing the throughput time from ten days to three days and which was reflected in better customer service, both sales and profits increased approximately 30%, inventory level was reduced by at least 60%, and WIP was reduced substantially.

More specifically, Browne et al. stated that JIT seeks to achieve the following objectives "1) zero defects, 2) zero inventories, 3) zero handling, 4) zero set-up time, 5) zero breakdowns, 6) zero lead time, and lot size of one" (1996, p.218).

2.3.4.2.2 Requirements and assumptions of JIT

Helms (1990); Vora et al. (1990) and Jewitt (1995), have pointed out several requirements for the successful implementation of JIT system, they are:

- Understanding what JIT is really about and what is not
- Getting top management commitment
- Preparing people through training to accept ongoing programme of continuos improvements
- Using a pilot project before implementing JIT system

Furthermore, Wild (1996) has summed up the requirements for effective JIT in: demand stability, vendor reliability (to ensure reliable supply), good communications, preventive maintenance, total quality control, management commitment, employees involvement, worker flexibility and low variety of items being processed.

2.3.4.2.3 JIT in MPC system framework

According to Vollmann et al. (1992) the JIT system relates to the three areas in MPC framework (front end, engine, and back end). In the back end area, JIT makes major improvements such as reducing costs of detailed shop scheduling, a significant reduction in work in process and lead times, and achieving better vendor scheduling. In the engine area, it plays a vital role in reducing the number of parts planned and the number of levels in the bill of materials (BOM) and which is reflected in reduction in the complexity of detailed materials planning. Also, in the front end, JIT has some impacts.

The implementation of JIT system requires production plans and master production schedules that provide degree of level capacity loading which is necessary for smooth shop operations. This will lead to stable schedules and a reduction in lead times. Within JIT environment companies follow marketing strategy make to order or assemble to order instead of make to stock which may enable them to respond customers orders. This in turn can impact on demand management activities in the front end area.

2.3.4.3 Optimised Production Technology (OPT)

OPT has its origins in Israel from the very beginning of the 80s, when Israeli physicist Eliyahu Goldratt was examining the goals and procedures in manufacturing organisations. His recommendations for action were presented in easily understood book (The Goal). This book introduced a new philosophy termed OPT (Optimised Production Technology), which emphasised on the main goal of a manufacturing companies -How To Make Money (Ptak, 1991).

Matsuura et al. (1995) had concluded in their study that OPT is understood by Japanese users as technique which utilises the OPT software package in scheduling. It is connected with finite loading which makes clear the relationship between scheduling and capacity availability. It starts with a specified capacity level for each work centre or resource grouping, this capacity is then allocated to work orders. Therefore, it can be considered as method for scheduling work orders (Vollmann et al., 1992).

On the other hand, it is understood as developing the capacity to prevent bottlenecks and controlling the capacity and materials flow for increasing the capacity utilisation of bottlenecks by Finnish users (Matsuura et al., 1995). In the aggregate, can be considered from two points of view, first, the OPT approach to manufacturing and planning control and second, the OPT software product.

2.3.4.3.1 Goals and significance of OPT

According to Aggarwal (1985) and Dilworth (1993), an objectives of OPT system are to maximise the use of critical resources namely, maximise utilisation of the bottlenecks and minimise WIP inventories and lead times through synchronising the flow of items through a factory. It helps manufacturing companies to determine priorities for each operation using a weighted function involving a number of important criteria such as: due dates, necessary safety stock and use of bottleneck machines.

Furthermore, it determines the duration of the fixed period and the optimal batch sizes for each component or subassembly in process at each machine or resource, and also use of the nonbottleneck resource beyond the quantity required to match the bottleneck-produced items will produce needless WIP. Ptak (1991) argues that OPT system helps manufacturing companies to build what is required from the market when it is required. Browne et al. (1996) have indicated that the main goal of OPT system by manufacturing companies is to make money. This goal can be represented by three financial measurements as follows: a) net profit, b) return on investment, and c) cash flow.

In sum, OPT is intended to determine the bottlenecks, ensuring that these resources are fully utilised, then scheduling use of nonbottlenecks in concurrent with the bottlenecks (Dilworth, 1993).

As cited in Browne et al. (1996, p. 306), the bottleneck is defined by Bylinsky (1983) as:

> "a point or storage in the manufacturing process that holds down the amount of product that a factory can produce. It is where the flow of materials being worked on, narrows to a thin stream."

2.3.4.3.2 Requirements and assumptions of OPT

Browne et al. (1996) reported that there are important requirements of the implementation of OPT system: a) the need for shop floor supervisors and others to have confidence in the schedule presented to them by the computer, b) it requires a large and complex production database, c) it requires determining a product network which requests that the process and product (BOM) data be brought together.

In general terms Dilworth (1993) and Browne et al. (1996) have pointed out that the main assumptions of OPT are: the enormous data not required compared to the others MPCs such as MRP systems, the accurate data on the bottlenecks resources and the products which visit those resources are needed, the plant assembled products instead of or in addition to selling individual components, the demand exceeds the capacity of the plant, and there is a bottleneck (s) that limits the production rate of some components of the products.

2.3.4.3.3 OPT in MPC system framework

It is both interesting and helpful to determine where OPT can be put in the general MPC system. According to Vollmann et al. (1992) OPT system works in all three areas in the general MPC system namely, the front end, the engine and the back end as illustrated in Figure 2.1. However, it is better seen as encompassing much of what's in the engine and end back, whereas it combines them in a way what that allows manufacturing companies to plan both materials and capacity simultaneously.

Furthermore OPT can accomplish some functions in the MPC framework. The OPT system depends upon the bottleneck resource and which plays a vital role for determining the production outputs, increasing throughput through better capacity utilisation of the bottleneck facilities. It helps to determine a lot size by distinguishing between a transfer batch (the quantity that moves from operation to operation) and a process batch (the total lot size released to the shop). Any differences between the two will be held as WIP inventories in the shop. In essence, a transfer batch should be built up behind any operation before its start.

Also, the work centre only produces a transfer batch whatever the build-up behind it, unless the finite scheduling calls for several batches. The lot size is relating to a scheduling approach in OPT which calls Drum-Buffer-Rope. This works as follows: the material is moved as possible through nonbottleneck operations until it reachs the bottleneck (the rope). Then, the work is scheduled for maximising efficiency (large batches) i.e. the drum. Thereafter, the work again moves as fast as it can to the finished goods (buffer).

2.3.4.4 Comparison of MRP, JIT, and OPT

In the aggregate, based on the literature review all three new production management systems have certain limitations and strengths which are summarised in Table 2.1 below:

Table 2. 1 Comparison of MRP, JIT, and OPT.

Item	MRP	JIT	OPT
Development era	1960s	Mid 1960 to 1970s	1980s
Reasons for development	Eliminate the need to forecast	Eliminate all waste forms	Maximise utilisation of capacity at the bottlenecks
Early gurus	Oliver Wight George Plossl Joseph Orlicky	Dr Cho Shigeo Shingo	Eliyahu Goldratt
Approach	MPC system	MPC system	MPC system
General assumptions	Stable and deterministic MPS Safety stock not required The lead times is fixed Infinite capacity Dependent requirement calculated from BOM explosion	Stable and level MPS Total quality Short lead time No supply variability	The enormous data is required compared to the others MPCs The accurate data on the bottlenecks is needed The plant assembled products The demand exceeds the capacity of the plant There is a bottleneck (s)
Application areas	Assembly and fabrication	Repetitive	Batch production
The scope	Influence the when the product is manufactured	Influence the what, the how and the when of manufacturing	Influence the when the product is manufactured
Key failing	Capacity requirements planning has a relatively low utilisation by MRP users Using the average of lead time as an actual lead time for planning	It only useful when use in repetitive industry It is not useful when company's supplier are local and captive	It does not provide a sense of hierarchical planning It seems to focus on a technical solutions
Basic elements	An inventory control system BOM Accurate routings for parts / components	An inventory control system BOM Accurate routings for parts / components	An inventory control system BOM Accurate routings for parts / components
Planning	Planned inventory Capacity planning Projected cash flow	No No No	Planned inventory Capacity planning Projected cash flow
Early users	Black and Decker	Toyota	M&M/ Mars candy company
Control	Detailed sequence and schedule Priority control & rescheduling Data collection	Detailed sequence and schedule Priority control & rescheduling Data collection	Detailed sequence and schedule Priority control & rescheduling Data collection
Implementation	Difficult, Complex, & Expensive	Difficult, Simple, & Expensive	Difficult, Complex, & Expensive
Benefits to people	High for management Low for shop floor employees	High for management High for shop floor employees	High for management Moderate for shop floor employees
Maintenance	Difficult, Complex, & Expensive	Easy and Cheap	Difficult, Complex, & Expensive

2.4 Why MRP systems?

The previous argument reveals that manufacturing companies may confront the problem of which solution to adopt -MRP, JIT, or OPT. The response is difficult because the solution for one industry is not necessarily the answer for all industries or even all companies within one industry (Ptak, 1991), also each system is sound in its own way and may be able to achieve the required improvements such as low cost, high-quality, on time production (Aggarwal, 1985). Furthermore, each system can be considered as a panacea for achieving the required improvements (Carrie et al., 1994).

Within this perspective, Greenhalgh (1991) asserts that manufacturing management may face some difficulties in the selection of the best manufacturing planning and control systems in order to meet current and future needs. These difficulties may stem from, firstly, that manufacturing companies must understand what each approach does well and not so well and the type of problems which might arise during implementation, secondly, they must realise that any new technologies related to manufacturing will continue to develop, namely, these new systems must not be seen as a final solution. Lastly, they should remember that any change has to be related to true business needs. However, Greenhalgh does suggest three key factors that may help manufacturing company to select the right system or systems. They relate to the degree of impact of the expected system on a) product performance, b) delivery reliability, and c) price.

In same direction Steele et al. (1995) has pointed out that the production environment such as the stability and simplicity of schedule procedure, lot-sizing rule, capacity constraints, demand (Lin et al., 1993) and the predictability of lead time can be considered as major factors in system choice.

Moreover, three operating factors have a great impact on system choice, they are: Master Production Schedule (MPS) volume variation, MPS mix variation, and set-up time/lot sizes. Plossl (1995) has argued that there is no single best MPC system for manufacturing planning and control, because the tool of planning and control, like the weapons of war, namely, include many techniques usable in many ways. All in all, the future success of manufacturing cannot depend on only one of the new MPCs, manufacturing company has to draw from the entire series of these systems what can enable it to achieve its goals (Ptak, 1991).

However, a review of the literature reveals that there is some consensus among researchers and practitioners concerning the widespread implementation of MRP systems compared to the other MPCs. Goh (1984); Cooper and Zmud (1989) and Sandeep (1992), pointed out that of the many 'Computer Aided Production Management' (CAPM) systems, MRP I/MRP II systems are still number one concerning their widespread implementation compared to the other new manufacturing planning systems such as JIT and OPT.

Browne et al. (1996) argue that MRP systems have almost certainly, been the popular implemented large scale production management systems since the early 1970s. Several thousands systems of MRP systems (MRP I, Closed-Loop MRP I, MRP II) are in use within manufacturing companies around the world.

Newman & Sridharan, (1992) found in their study about the selection of the best manufacturing planning and control system by manufacturing companies in the US, that 103 out of 185 manufacturing companies surveyed had implemented MRP systems, while 14 companies had implemented JIT system, only 9 companies had implemented OPT system, and the rest of the companies still implemented the traditional systems (Reorder Point Systems- ROP). Also, they had concluded that MRP systems appear to be most versatile and are able to cope with increased complexity in manufacturing. In this regard Robertson et al. (1996) stated that one particular form of computer aided production management (CAPM) which has been heavily promoted by technology suppliers as best practice is MRP/MRP II.

Furthermore, Lunn (1996) suggested that MRP systems are still considered as one of the best methods to reduce inventory which has been viewed by business and industry as a necessary evil, because too little of it may cause the interruptions in the operation, and too much of it will affect negatively on the achieved profits (Taha, 1992).

Again, Turbide (1995) showed that despite the fact that the idea of MRP dates back more than thirty years, and its software package has been around since the 1970s, MRP is still number one for application software structure for today's manufacturing management. John and Charlotte (1996) reported that MRP II is considered the most popular production scheduling package in the UK.

In this connection, Carrie et al. (1997) suggest that:

> "MRP II continues to grow in popularity despite persistent problems with its implementation ....Surveys continue to show increased adoption rates significant implementation problems and research from as early as the 1970s suggests that these problems have not changed much over the years" (1997, p.2).

Consequently, one can say that Materials Requirements Planning (MRP I) and its extension Manufacturing Resources Planning (MRP II), the much proclaimed systems, have gained the acceptance from both academics and practitioners as an important factor for improving manufacturing processes.

2.5 Evolution of MRP systems

Though MRP concepts have been and are still extensively used in the management of manufacturing companies, it is not an easy concept to define. It would be both interesting and challenging to trace the development of the MRP system in order to minimise the confusion concerning these three separate but related aspects of MPCs i.e. MRP I, Closed-Loop MRP, and MRP II. However, no endeavour will be made in explaining the technical details of the system.

MRP I was expanded to include capacity requirements planning, with provision of feedback to adjust the capacity to meet the production requirements. Therefore the term closed loop MRP system was used to represent this matter of development of MRP system.

In the 1980s another development of MRP was evolved to convert the schedule information into useful corporate-wide game planning information. This helped in that the change of priorities and order due dates within the Master Production Schedule (MPS) can be reflected in both materials plan and capacity requirement plan. This development refers to Manufacturing Resources Planning system -MRP II (Spreadbury, 1994). However, the original idea of MRP has continued to support materials planning, and launching of shop and purchase orders (Sandeep, 1992).

Therefore, the next subsection is intended to discuss the details of the evolution of MRP systems. A review of the literature reveals that there are two major approaches to materials control: Reorder Point (ROP) and Material Requirements Planning (MRP). However, the assumption of independent demand is violated if the reorder point approach is used to calculate assembly products with dependent demand. This caused the development of MRP which serves to deal with dependent demand (Mady, 1992; Dilworth, 1993; Wild, 1996). Therefore, this section begins with an introduction of Reorder Point Systems (ROP), followed by the development of MRP systems.

2.5.1 Reorder Point Systems (ROP)

A reorder point system is used for inventory control in two successive steps: the first, to determine when to order, and the second, to identify how much to order. The answer to the two questions is as follows: when the inventory level, including existing orders on suppliers, reaches a predetermined reorder point, a new order is placed on the supplier (or production). A reorder point is usually specified by the inventory level at which a new order must be placed. Having decided to place an order point (when the reorder point is reached), the next decision is to determine how much to order. The order size is often calculated using the "Economic Order Quantity" (EOQ).

2.5.1.1 Two-Bin System

One of many approaches in ROP systems is Two-Bin system which was widely used before MRP. It places a quantity (equal to the order point quantity) in a separate storage bin, not to be touched until the working stock is used up. When accessed, a replenishment order is placed (Plossl, 1995).

The major advantage of this method is the obvious reduction of clerical work because it does not need a continual inventory record. On the other hand the major disadvantages of this system are: in some cases is difficult to keep the stock in the two bins properly separated, in turn will be there high inventory (Dobler and Burt, 1996), and also the items are ordered because of the rule instead of need (Sandeep, 1992).

2.5.1.2 The ABC Inventory System

Another inventory system was widely used before MRP system, is known as ABC Inventory Classification or Pareto Analysis. The ABC technique is identified as a simple procedure that can be used to isolate the items that require special attention in terms of inventory control.

According to Taha (1992); Dilworth (1993) and Elkhouly (1994), the idea of the procedure is that the total cost of materials which will be used over a specific period is computed first. This amount is determined by multiplying the unit cost of each item by the estimated total usage for the period. Once total usage costs for every item is computed, they are listed in descending order, the highest first and lowest last. Two percentages are then computed: the percentage of each item's cost to total cost and the percentage of each item's units to total units. The items are divided into three classifications as follows:

Class A. High value items: The 15 to 20 percent of the items that account for 75 to 80 percent of the total annual inventory value.

Class B. Medium value items. The 30 to 40 percent of the items that account for approximately 15 percent of the total annual inventory value.

Class C. Low value items. The 40 to 50 percent of the items that account for 10 to 15 percent of the annual inventory value.

Many advantages can be achieved of the ABC technique for instance, it is a very valuable management tool for identifying and controlling important inventory items (Dobler and Burt, 1996) and it is first step in improving inventory control performance (Vollmann et al., 1992).

The major operational problems associated with the implementation of the Pareto analysis are summarised by Sandeep (1992) as follows: how many groups or categories must be used?, where should the class boundaries be?, what should the ordering frequency be for each category?, and how much protection should be used in each class initially?.

All in all, one can conclude that the ROP systems are not effective in the case of dependent demand "for instance, a car door is a dependent demand item in the production of a car". This may stem from the following:

1. The demand for the required items is lumpy due to "the dependency of component demand on the demand for their parents gives rise to a phenomenon of discontinuous

demand at the component level" (Browne et al., 1996, p.97). This will lead to slack inventory, if manufacturing company had decided to use EOQ for inventory control.

2. When the production line is long, the distance between an item and the final assembling station becomes far, the lumpy and uncertain demand likely to be increased. In such matter, if manufacturing companies had decided to use EOQ systems, they should keep a high level of inventory as a safety stock in order to ensure that the production processes will continue without halting.

3. The ordering technique is capacity-insensitive i.e. no consideration is given as to whether there is sufficient capacity and components to meet the schedule.

Consequently, the MRP system was created as a new manufacturing planning and control system to help manufacturing companies to overcome the above mentioned problems.

However, it is necessary to contend here that the need for the traditional inventory control techniques for other types of production systems will continue to be in demand for a long time to come (Taha, 1992).

2.5.2 Material Requirements Planning (MRP I)

Material Requirements Planning (MRP) is a technique used to determine what requirements of materials used in the manufacturing operation are needed, how many are needed, when they are needed, and when they should be ordered in order to they likely to be available when needed.

In many manufacturing organisations, MRP has been considered as a computerised information system for managing dependent demand inventory and scheduling stock replishment orders (Duchessi et al., 1989; Manthou et al., 1996; Roberston et al., 1996).

Matsuura et al. (1995) have pointed out that MRP in a narrow sense means a technique which explodes and calculates material requirements based on master production schedule, using bill of material and inventory status data. It is concerned essentially with the scheduling of activities and the management of inventories. Specifically, it is useful where there is need to produce components, items or sub-assemblies which themselves are later used in the production of a final product (Wild, 1996).

Within this perspective, MRP has been considered as a dynamic economic order quantity model which may help to review the inventory level periodically so as to provide a timely delivery of required materials for different stages of the production process (Taha, 1992). Furthermore, MRP system appears to work best for companies with mass production assembly lines (Aggarwal, 1985) and in batch manufacture (Wild, 1996). Overall, it assumes unequal demand, attempts to achieve zero stock-outs, and focuses on setting priorities (Aggarwal, 1985).

The main inputs of MRP are: a) the master production schedule (MPS) which shows how much of each end item is wanted and when the items are wanted. In general terms, Spreadbury (1994) argues that Master Production Scheduling (MPS) plays a vital role as a balance between manufacturing demands factors (customer orders, forecasts, safety stocks, inter-plant requirements, and export requirements) and manufacturing resources- supply factors (material, inside capacity, and outside capacity), b) the bill of materials computer file (BOM) which identifies the components parts of a final output product at each level, and c) the inventory master computer file which shows the available inventories of all materials, subassemblies, components, etc.. required for the manufacture of the end product. This will enable a company to determine requirements for timing individual products and work schedules (Elkhouly, 1994; Wermus and Pope, 1995; Wild, 1996).

There are a variety of reports that can be constructed from the information obtained from an MRP system. They are the following: current orders release to purchasing the quantity of each item with due date requirements, planned orders indicating the quantity and timing of orders to be released in future time periods if the current master schedule is to be accomplished, current and planned order releases for in-house production, with achievement date requirements, reschedule notices indicating which order due dates need to be changed and dates to which they must be changed, and finally an MRP system may replan and schedule the material requirements in light of the notices extracted from the MPS (Elkhouly, 1994; Dobler and Burt, 1996). The previous reports can be used to determine time-phased gross and net requirements for manufacturing inventory. And also, can be used to determine feasible delivery dates for customer orders.

In sum, as shown in Figure 2.5 the processing logic of MRP centres on the development of a materials planning record for each item. MRP takes the data contained in the master production schedule, bill of materials, and inventory record file shown at the top. This presents the gross requirements or the anticipated usage of the item projected into the future. It breaks down this data into its component parts, compares this requirement against existing inventories, and seeks to schedule the parts required against available capacity. Hence, it produces a schedule for all component parts, indicating purchasing requirements and the expected shortages due to capacity limitations. This processing logic of MRP will be undertaken on a repetitive basis (Dobler and Burt, 1996; Wild, 1996).

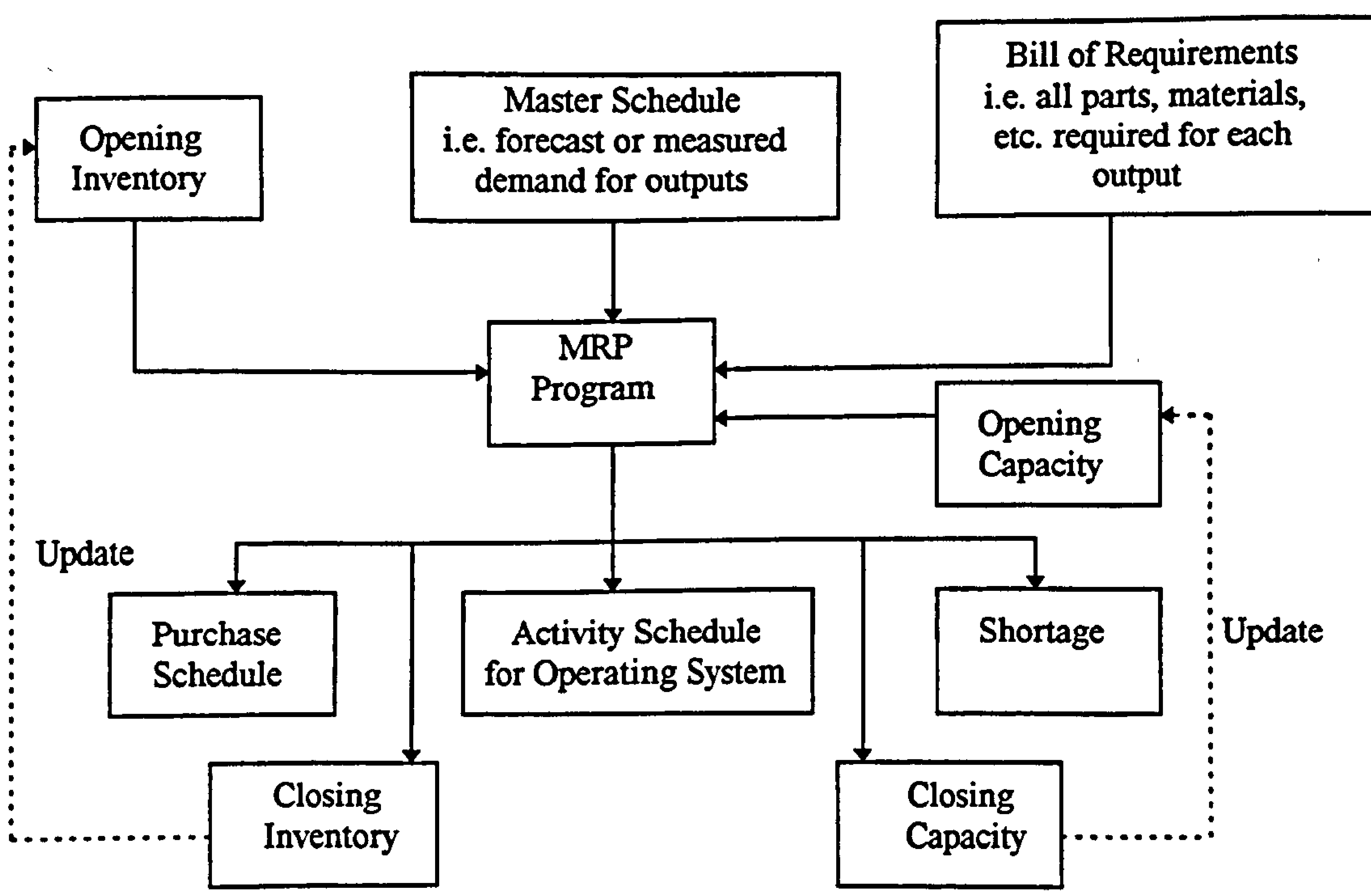

Figure 2.5 Basic MRP I structure (Adopted from Wild, 1996: P.215).

However, MRP lacks a solid link between a capacity planning capability and the execution functions of production activity control and purchasing (Diamond, 1997), and also it does not allow determination of actual requirements until the system plans an actual lot size for a given run although real demand can be determined in the light of a combination of existing customer orders and additional forecasted demand (Chamberlain and Thomas, 1995). Thus, the development of the MRP system that occurred in order to fill this gap was identified as the closed-loop system.

2.5.3 Closed-Loop MRP

A Closed-loop MRP incorporates MRP in a narrow sense (expanding and calculating material requirements) as a core, in which functions such as master production scheduling, capacity requirements planning, and shop floor control, are attached (Matsuura et al., 1995). It provides feedback to scheduling from the inventory control system. This feedback links between capacity planning and MRP system.

Therefore, it is a system that provides the means for determining feasibility of the company's production plan (i.e. does the company meet the production requirements?). Furthermore, the main objective of developing the MRP closed loop concept is to help manufacturing companies to cope with the complexities of production planning (Wermus and Pope, 1995).

While the closed loop system extends the capabilities of MRP I system by including capacity planning functionality and feedback system that monitors and reports on the progress of open shop orders and purchase orders, Manufacturing Resources planning- MRP II system integrates the closed-loop MRP I with other modules, including forecasting, general ledger, accounts receivable, accounts payable, finished good inventory and order entry (Duchessi et al., 1988), and creates a complete closed-loop management facility that touches all of the major functional areas of the business in order to monitor all of the resources of a manufacturing firm.

Figure 2.6 shows the processing logic of the closed loop system. It denotes a link between capacity requirements planning and master scheduling, MRP, and the execution functions of production activity control and purchasing which include input/output measurement, detailed scheduling and dispatching on the shop floor, and delay reports from both shop floor and vendors. It also indicates that the feedback from execution functions (i.e. questions and output data) are looped backed up the system for verification and, if necessary, modification (Chase et al., 1998). All in all, the system sums up all the needs created by an explosion of product requirements in the master schedule. If adequate capacity does not exist at a work centre, the feedback results in a revision of the master schedule or actions taken such as overtime, increasing workforce etc.

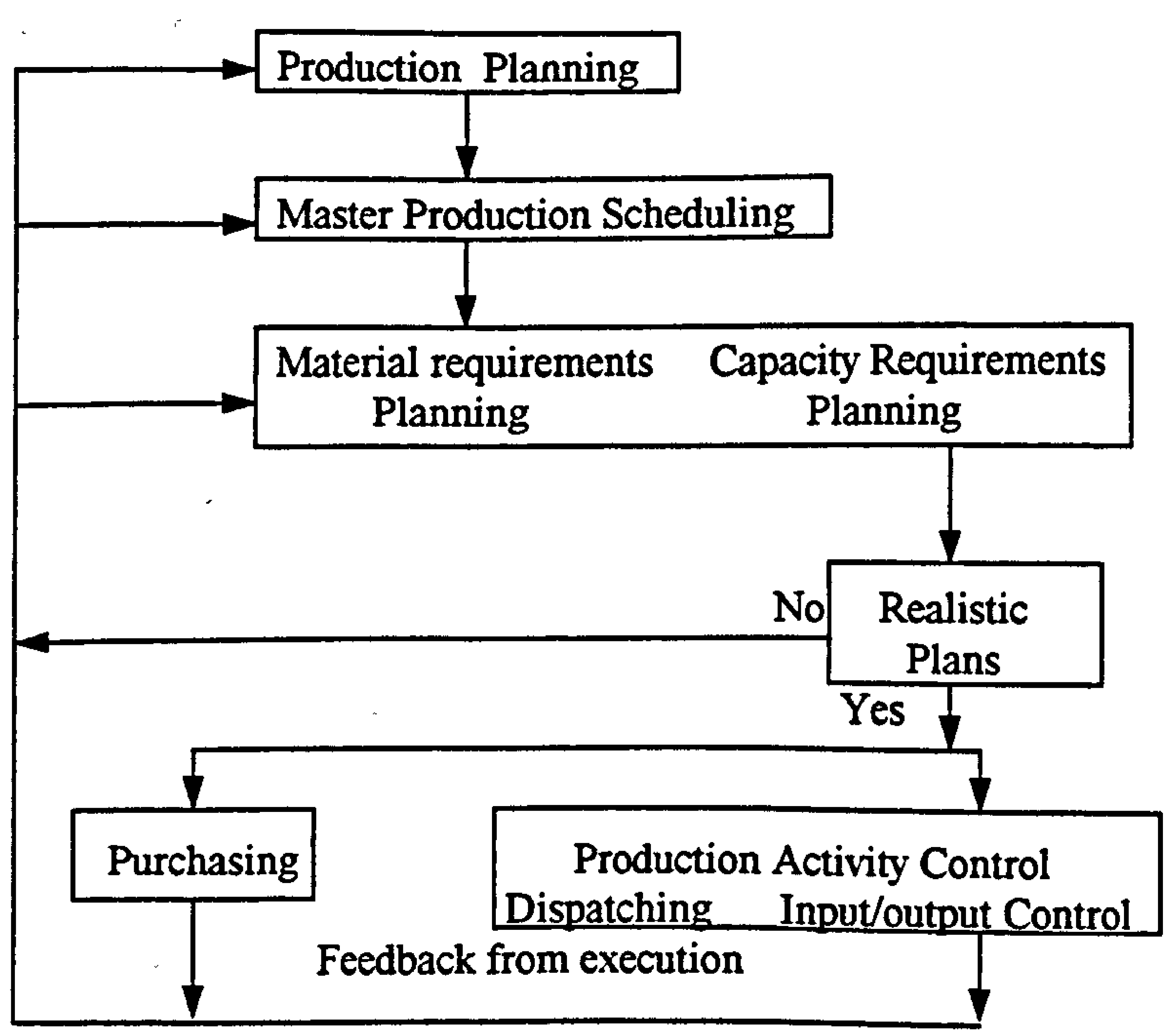

Figure 2.6 Basic Closed-loop MRP (Quoted from Browne et al., 1996: P.131).

Thus, the closed loop system can effectively help manufacturing companies to replace the existing system (informal- does not work very well) with a formal system (that works). Feedback is a self correcting process (Fisher, 1981). However, it lacks a link to strategic planning as the manufacturing plans are not strategically estimated and lacks an input from the other departments- marketing, finance, engineering which may result in conflicting goals. Consequently, the last step, to date, in this evolutionary process is known as Manufacturing Resource Planning -MRP II (Dobler and Burt, 1996). In this connection, Browne et al. (1996) have pointed out that Manufacturing Resources Planning (MRP II) represents an extension of the features of the MRP I system through Closed loop MRP in order to support many other manufacturing functions beyond material planning, inventory control, and bill of materials control. Accordingly, MRP II was evolved from MRP I by a gradual series of extensions to MRP system functionality.

2.5.4 Manufacturing Resources Planning (MRP II)

MRP II is a company-wide system which involves every facet of the business. "What if " questions can be asked to determine the effects of changes in situations/plans on the organisation and its profitability facts. The simulation capability of such system allows decision makers to compare alternative strategies based on actual manufacturing constrains and conditions. This facilitates the formulation of effective business plans with inputs from all departments.

While MRP I only deals with material ordering aspects of operations control, MRP II takes the concept further by considering the resources available. MRP II recognises when a material requirements plan is infeasible (e.g., when production schedules generated are greater than capacity) and can suggest measures to remedy this.

MRP II integrates computer control of materials with other areas of computerisation within the business including finance, marketing, sales design and engineering. MRP II is often seen as closing the control feedback loop by the constant monitoring and upgrading of the computer-based systems of the business, so it can be seen as ensuring the effective operation and control of the wider manufacturing systems (Forrester et al., 1995).

MRP II can be considered as an extension or a development of MRP, but is very much broader in concept and application (LaPlante, 1994; Wild, 1996) or as a step beyond the closed loop system. It might allow a company to use work orders to track labour and material utilisation where they vary from job to job, but to diminish transactions by removing work orders where machine or labour utilisation is standard (Parker, 1995).

Moreover, MRP system looks ahead to see when company need, then backs up to see when company ought to release it. The significant feature of the MRP system that gives its powerful capabilities is its rescheduling features (Goh, 1984).

In the aggregate, Browne et al. provide the main characteristics of MRP systems as illustrated below:

- "MRP is product oriented in that it operates on a BOM to calculate the component and assembly requirements to manufacture and assemble a final product.

- MRP is future oriented in that it uses planning information from the master production schedule to calculate future component requirements instead of forecasting based on historical data.
- MRP involves time phased requirements in that during MRP processing, the requirements for individual components are calculated and offset by their expected lead times to determine the correct requirement date.
- MRP involves priority planning in that it establishes what needs to be done to meet the master schedule, as opposed to what can be done, given capacity and material constraints.
- MRP promotes control by focusing on orders, whether purchase orders or orders for the manufacturing plant."(1996, pp. 100-101).

Figure 2.7 shows the processing logic of Manufacturing Resource Planning (MRP II). Spreadbury stated that MRP II "mechanics comprise a variety of functions each linked together. There are business planning, sales and operations planning, master production scheduling, MRP, capacity requirements planning and associated shop floor execution systems. It illustrates how these functions are integrated. In order to close the loops and provide true business integration, financial management is also included within MRP II, and this helps the business and sales and operations planning functions to operate efficiently, through incorporation of "what if" and financial forecasting based on one set of numbers" (1994, p.153).

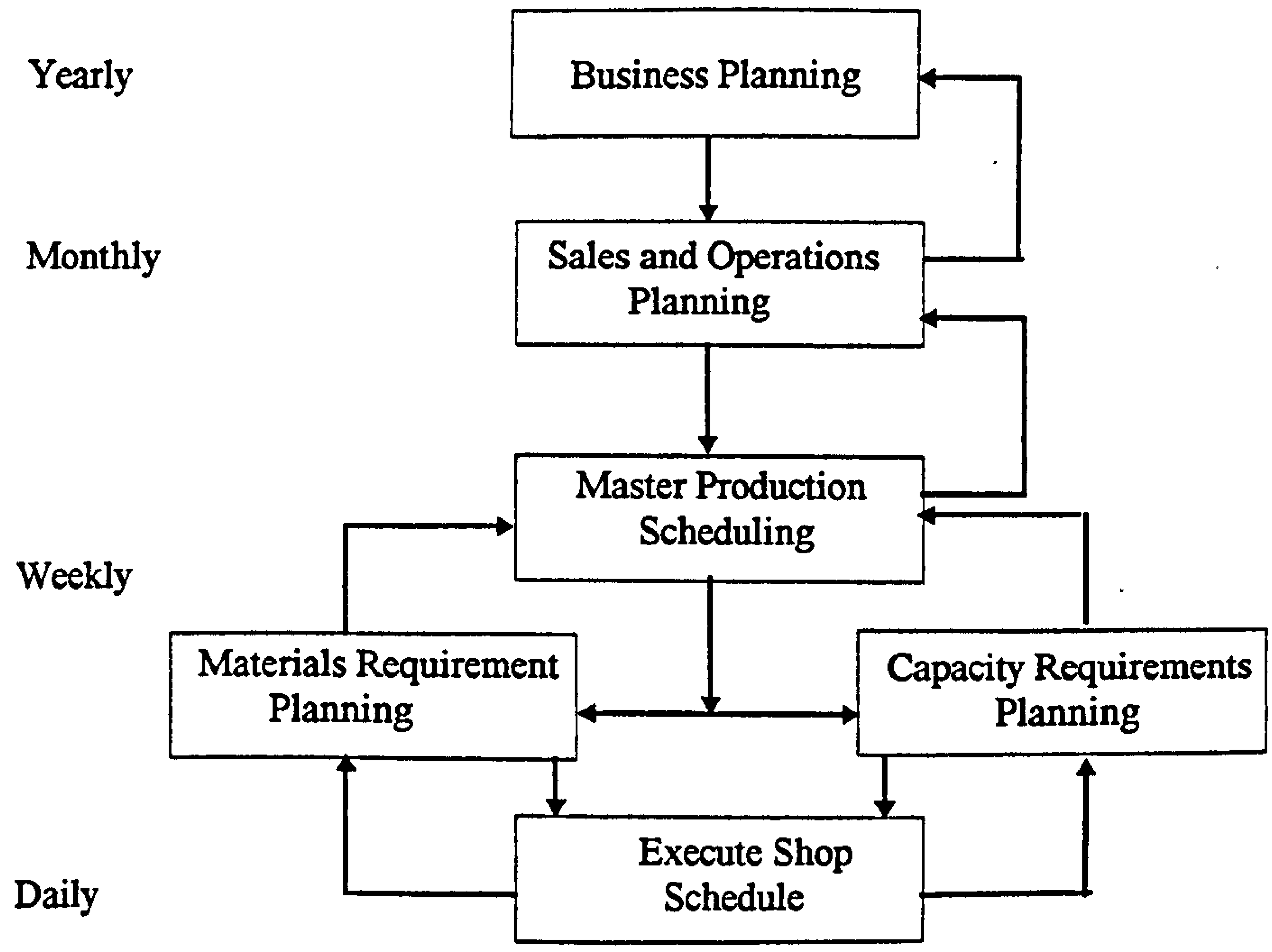

Figure 2.7 MRP II: integration of planning functions within the Closed-Loop (Straight copy from Spreadbury, 1994: P.153).

In the aggregate, MRP II can provide production schedules, purchase orders and material requirements on specific jobs. Therefore, one can conclude that the accurate database constructed by implementing MRP II system helps for both controlling and planning functions, and simulation capability. Therefore, MRP II opens up a new manufacturing era.

However, it is worth mentioning to present the main factors that may impede the practice of MRP system by manufacturing companies and also the main areas for promoting MRP practices. This before investigating the critical factor affecting MRP implementation and the benefits obtained from the implementation of MRP system.

2.6 The state of practice of MRP/MRP II systems

As pointed out by several writers such as Anderson et al. (1982); Laforge and Sturr (1986) and Sum et al. (1993), investigation of the practice of MRP system can be accomplished by covering several key issues, such as: MRP company profile (i.e. size and age, type of manufacturing system, type of manufacturing process and layout), MRP system characteristics (i.e. hardware and software, degree of computerisation, degree of integration, and system features), the stage of MRP implementation (i.e. user class), implementation process (i.e. initiator of MRP and implementation problems), MRP system growth, factors that may impede non-users to implement MRP systems and finally the main areas for promoting MRP system.

For the purpose of this thesis, all of these issues will be covered in detail in section (2.8) in discussing factors affecting MRP suitability and success of MRP implementation except for the last two issues which will be discussed in the following subsections:

2.6.1 Promoting areas for MRP implementation

As pointed out by Sum and Yang (1993) and Ang et al. (1995) several areas can help to promote MRP systems, they are: government support (e.g., grants, incentives), education/ training provided by government/professional bodies, education/ training provided by software/ hardware vendors, information sharing among users, and low cost consultancy. They had concluded from their studies about the implementation of MRP systems on 128 Singaporean companies, that the Singaporean government support (e.g., grants, incentives) and education/ training provided by government/professional represent the main areas for promoting MRP in Singapore.

Related to the above mentioned results, the literature reveals that governments still play a vital role with regard to encouraging manufacturing companies to adopt advanced manufacturing technology (AMT) such as MRP systems whether in developed countries such as the UK or in less developed countries such as Egypt or in the newly industrialising countries such as China.

In the UK, DTI (1991) has published a report comprising the government response to the Advisory Council On Science And Technology (ACOST) concerning the implementation of advanced manufacturing technology within manufacturing companies in the UK. This revealed that the British government still plays a significant role in the promotion of advanced manufacturing technology within British companies. For example the DTI conducted a programme concerning advanced information technology which seeks to develop techniques for improved usability of IT systems. The government is doing all it can to fill the gap of the shortage of the supply of engineering graduates through increasing the number of students applying for technological courses in the 90's. Likewise, other related work was conducted by the Organisation for Economic Co-operation and Development -OECD (1991) which includes the western countries including the USA, in addition to Turkey, and concluded that most OECD governments have encouraged firms to implement AMT with a range of incentives and infrastructural support such as: training initiatives, financial incentives to invest in new equipment, develop new products and software.

Per-lind (1991) pointed out in his study about computerisation in less developed countries, with special reference to NASCO company as a biggest automobile company in Egypt, that the Egyptian government plays a vital role in encouraging manufacturing companies to implement new production technology such as MRP system in order to improve its productivity.

In China, Davis (1995) reported that the Chinese government seeks to encourage efficiencies in the industrial sector by implementing MRP II system to achieve global competitiveness.

Roberston et al. (1996) have pointed out that the vendors of Computer Aided Production Management -CAPM play a vital role for promoting both MRP I and MRP II in the UK as a best practice of CAPM systems. Subsequently, they may have recognised the potential significance of users knowledge and application of software in order to infusion occurs.

2.6.2 Factors that may impede Non-users to implement MRP systems

A review of the literature reveals that there are several obstacles impeding manufacturing companies to implement any new manufacturing technology such as MRP systems. Ang et al. (1995) found in their study about the critical success factors in implementing MRP and government assistance on 128 companies within Singapore that the main reason for Non-MRP companies not implementing MRP system is a lack of company expertise in MRP in Singaporean companies.

Another obstacle that may impede the implementation of MRP systems is that some manufacturing companies do not feel it achieves big enough benefits. This may go back to the fact that the most of implementers reported a dissatisfaction with MRP use (Aggarwal, 1985; Fintech, 1989; Hill, 1993; Browne et al., 1996; Carrie et al., 1997).

Newman & Sridharan (1992) found in their study about the selection of the best manufacturing planning and control system by manufacturing companies in the US, that ROP users had obtained the best performance among MPC systems implemented by American companies. This means that some Non-MRP companies may be successful without implementing MRP systems.

In fact the implementation of any new manufacturing technology by manufacturing companies is not an easy task. Drayson et al. (1986) have reported in their study with regard to the implementation of robotics in a food manufacturing company in UK that the problems associated with implementation of A.M.T such as MRP systems are due to these technologies being too far ahead of the company's abilities to manage. Furthermore, Beatty and Gordon (1988) reported that people within manufacturing companies may resist the implementation of a new manufacturing technology such as an MRP system for fear that they will lose their power and status.

Duchessi et al. (1989) argue that companies implementing or considering implementation of MRP system should receive advice on how to manage effectively the implementation process. Therefore, the next section is devoted to investigate effectiveness of the state of practice of MRP system.

2.7 The Effectiveness of MRP practices

Browne et al. (1996) suggested that the investigation of the state of practice of MRP systems relates primarily to understanding the effectiveness of such systems for the companies that use them. As a system is effective if it achieves its objectives or if it does what we need it to do (Johnson et al., 1974; Fisher, 1981; Browne et al., 1996).

Therefore, the effectiveness of MRP practices is measured by the benefits obtained from MRP implementation. Consequently, the next section is devoted to present the expected potential benefits and the real benefits obtained from MRP implementation, then the key failings of MRP systems.

2.7.1 MRP implementation benefits

A review of the literature reveals that MRP benefits have been measured in three ways as follows: firstly, MRP implementation studies have measured MRP benefits by attitudes, intentions or behaviour of users (subjective or intangible benefits or user satisfaction) such as Duchessi et al. (1988); Sum and Yang (1993) and Sum et al. (1995).

Secondly studies such as Anderson et al. (1982); Anderson and Schroeder (1984); Laforge and Sturr (1986) and Cerveny & Scott (1989) have measured MRP benefits by actual use or improved performance measures. Thirdly studies such as White et al. (1982) and Schroeder et al. (1981) have measured benefits by both improved performance and subjective benefits.

2.7.1.1 Tangible benefits

MRP benefits can be measured by improvement in tangible measures of manufacturing performance. These are inventory turnover, delivery lead time, percent of time meeting delivery promises, percent of order requiring "splits" because of unavailable material, and number of expediters. However, there is a difficulty in obtaining measures of actual use (White et al., 1982), because, often, companies cannot to keep track of the performance measures over time (Sum et al., 1995). Therefore, to assess improved performance the respondents (MRP users) are often asked to provide the experience that they would expect operating in today's economic environment with their pre-MRP production system, then to state the current experience given their stage of MRP development, and finally, state the future experience that they anticipate given total completion of their MRP development plans as in Anderson et al. (1982) and Laforge & Sturr (1986).

2.7.1.1.1 Increasing inventory turnover

Inventory turnover is basically the ratio of sales to the average inventory level. Therefore, it can be increased whether increasing sales or reducing inventory level. With MRP system, the company can increase its sales through improving the company's ability to react to changes in customer needs (Dilworth, 1993; Strzelczak, 1995); improving customer service by on-time delivery, and better quality (Cox and Clark, 1984; Sum et al., 1995). The company can reduce inventory level through balanced inventory, reduction in work in process inventories, and reduction in finished goods inventories (Smith et al., 1980; Cox and Clark, 1984). Several empirical studies reported that inventory turnover was increased as a result of the implementation of an MRP system such as Anderson et al. (1982) in their study about the state of the art of MRP practices on 679 companies in the US, and Laforge & Sturr (1986) in their study regarding MRP practices in a random sample of manufacturing companies consists of 107 companies in the US, and Cerveny and Scott (1989) in their study concerning MRP implementation on 433 companies in the US. This is shown in Table 2.2 below:

Table 2. 2 Increasing inventory turnover as a result of MRP implementation (sales/inventory-%).

Author	Country	Pre-MRP	After-MRP	Improvement
Anderson et al. (1982)	USA	3.2	4.3	+1.1
Laforge and Sturr (1986)	USA	4.5	7.9	+3.4
Cerveny and Scott (1989)	USA	4.6	5.5	+.9

2.7.1.1.2 Better delivery lead time (days)

Delivery lead time is the time that a customer waits between placing an order and receiving shipment (Bartezzaghi et al., 1994). Dilworth (1993) argues that the implementation of an MRP system helps manufacturing company to cut delivery lead time by keeping components on schedule and minimising parts shortages and which will be reflected in helping production meet assembly dates. Anonymous (1996) reported that lead times have been reduced from six weeks to less than one week at Bimba Manufacturing of Monee Illinois after implementing MRP system. Furthermore, this benefit was achieved empirically by the American users as shown in Table 2.3 below:

Table 2. 3 Better delivery lead time as a result of MRP implementation (number of days).

Author	Country	Pre-MRP	After-MRP	Improvement
Anderson et al. (1982)	USA	71.4	58.9	-12.5
Laforge and Sturr (1986)	USA	55.6	41.7	-13.9
Cerveny and Scott (1989)	USA	17.5	13.5	-4.0

2.7.1.1.3 Increasing percent of time meeting delivery promises (%)

With an MRP system, Singaporean companies could obtain a better meeting of delivery dates (Sum and Yang, 1993). MRP systems enable managers to calculate the requirements of each part or every subassembly week by week and helps to identify in advance possible delays or shortages. This will enable people in inventory control to reschedule dates for the released orders as an attempt to meet the promised deliveries (Aggarwal, 1985). Furthermore, the implementation of an MRP system will improve the percentages of promised deliveries because work orders are released based upon MRP need dates and are rescheduled based upon its output (Duchessi et al., 1989). It has helped Bimba Manufacturing of Monee at Illinois to achieve 95% on-time delivery (Anonymous, 1996). As pointed out several writers report increasing percent of time meeting delivery promises after implementing MRP system as shown in Table 2.4 below:

Table 2. 4 Increasing percent of time meeting delivery promises as a result of MRP implementation (%).

Author	Country	Pre-MRP	After-MRP	Improvement
Anderson et al. (1982)	USA	61.4	76.6	+15.2
Laforge and Sturr (1986)	USA	73.9	88.6	+14.7

2.7.1.1.4 Reducing percent of split orders (%)

Table 2.5 indicates that the implementation of MRP systems leads to the reduction of percent of orders requiring “splits” because of unavailable material. This is because the implementation of an MRP system requires that each part or every subassembly’s bill of materials (BOM) is accurate (Aggarwal, 1985).

Table 2. 5 Reducing percent of orders requiring “splits” because of unavailable material as a result of MRP implementation (%).

Author	Country	Pre-MRP	After-MRP	Improvement
Anderson et al. (1982)	USA	32.4	19.4	-13
Laforge and Sturr (1986)	USA	29	13.5	-15.5

2.7.1.1.5 Reducing number of expediters (number of people)

According to Plossl (1995) MRP systems can sustain priority control by attempting to make two dates coincide, the first is the due date which is allocated to open orders either put on the orders when released or revised by planners later, the second is need date which shows when orders are actually needed. These two dates are often unlike. If so, there is a need to move the need date either forward or backward by rescheduling in time from due date. MRP systems can signal either "expedite" or "de-expedite" order in order to reduce the divergence of the two dates. That is, MRP systems recommend changes (expedite or deexpedite) in due dates for orders (Dilworth, 1993). Table 2.6 verifies the previous mentioned benefit as follows:

Table 2. 6 Reducing number of expediters as a result of MRP implementation (number of people).

Author	Country	Pre-MRP	After-MRP	Improvement
Anderson et al. (1982)	USA	10.1	6.5	-3.6
Laforge and Sturr (1986)	USA	10.8	5.1	-5.7

2.7.2.2 Subjective benefits

Due to the difficulties in obtaining improved performance measures several studies have decided to measure MRP benefits using user satisfaction only. The data are interpreted as expressing user perceptions of the successful implementation of MRP systems as in Duchessi et al. (1988); Sum and Yang (1993) and Sum et al. (1995).

2.7.2.2.1 Improved competitive position

As pointed out by several writers such as Leng (1987); White and Wharton (1990); Lummus and Wilson (1992) and Sum and Yang (1993), manufacturing companies may adopt new production management systems such as MRP and JIT, as a response to regional and international competition pressures. These systems may enable manufacturing companies to ease these pressures through the continuous pursuit of greater productivity, lower costs and better customer service and which are reflected in improving competitive position.

Strzelczak (1995) argues that an MRP system can be considered as one of the basic tools which enables manufacturing companies to achieve better responsiveness to changing market demand. Furthermore, Duchessi et al. (1989) reported that Flo-Co systems, which is a leading manufacturer of steel teeming systems (control devices for regulating the flow of steel) at Illinois in the US, chose to implement MRP II as a part of an overall business strategy to be more competitive.

2.7.2.2.2 Reduced inventory costs

Anonymous (1996) reported that the biggest benefit obtained from MRP II implementation, by the company James Coney, was a 20% to 25% reduction in inventories, plus lower costs for holding stocks of obsolete inventory. Moreover, with implementation of an MRP system, the company can improve vendor relations (Dilworth, 1993) because it will be able to provide vendors with valid schedules of purchase orders. With that, the vendors can produce the items demanded more efficiently and at lower costs. This will be reflected in a reduction in purchase costs. Smith et al. (1980) reported that the company's Smith Valve has achieved inventory reduction of 16% after implementing an MRP system.

2.7.2.2.3 Increased throughput

Browne et al. (1996) defined throughput as the rate at which finished units are sold. With MRP systems companies can increase throughput whether through better capacity utilisation (Dilworth, 1993) or through reducing throughput times (i.e. the reductions in the inventory level) by providing the right components and parts at the right time and which is reflected in increasing manufacturing productivity (Duimering et al., 1993).

Furthermore, companies with high throughput efficiencies will easily out compete companies with low throughput efficiencies because they have the ability to shorten production lead times more than the others (Best, 1997).

Furthermore, increased throughput is reported by Sum and Yang (1993) as one of the major benefits obtained from MRP implementation in Singaporean companies.

2.7.2.2.4 Improved product quality

According to Sheldon (1991) quality cannot to be separated from MRP II. It is required as an attitude. The quality can be achieved if all data files such as bills, item master records are measured and clearly defined. Cox and Clark (1984) argue that the implementation of an MRP system will help companies to achieve better quality and this is reflected in obtaining better customer service. Virtually every company that uses an MRP system can enhance the improvement in the quality of life in manufacturing because the system provides the company with immense flexibility to reply to market demand (White et al., 1982; Wight, 1983). Furthermore, an MRP system provides the company with the ability to make products which show maximum value through attempting to make cost correspond to customers wants and resources in a given situation, namely making the production and marketing functions work closely together (Gordon and Marino, 1992).

2.7.2.2.5 Improved productivity

Several researchers have reported an improvement in the company's productivity as a result of MRP implementation (Sum and Yang ,1993; Sheldon, 1994; Sum et al. 1995). Sohal and Naylor (1992) highlight the company's productivity can be increased dramatically in consequence of reduction in throughput time and reduction in inventory. This can be achieved from MRP implementation (Dilworth, 1993). Furthermore, with an MRP system productivity of direct labour can be improved because the production will be planned in advance. With this knowledge, production orders can be scheduled to better utilise the available labour time.

2.7.2.2.6 Increased information on which to base decisions

One of the significant reasons for adopting MRP as the production management technique by manufacturing companies is because it makes use of the computer's ability to store data centrally and provide access to the large body of information that seemed necessary to run a company, and also, it helps to achieve coordination among various aspects of production such as engineering, production and materials (Sum et al., 1995; Browne et al., 1996).

According to Kneppelt (1981) an MRP II system can be used for the decision-making process in areas such as accounts payable, payroll etc. With an MRP system operations managers can make decisions concerning the rescheduling of orders and the cancellation or suspension of orders on the master schedule as the firm's priorities changes (Elkhouly, 1994). The firm can also monitor results, and when necessary, change direction, because the system provides data quickly, before time works its permutations (Kull, 1983) . In addition, the MRP data base allows managers to obtain reports on projected inventory levels, vendor delivery performance, lead time, the master parts, bill of materials, the manufacturing routing, and work centres (Browne et al., 1996).

It is worth mentioning that MRP is not an automatic decision system, it is a decision support system (DSS) which provides timely and valuable information to people who make the decisions and who make a company run such as sales order processing, forecasting, aggregate production scheduling, material requirements planning, master production scheduling, bill of materials, capacity requirements planning (Plenert, 1992; Dilworth, 1993). Furthermore, Duchessi et al. (1989) found that successful companies in MRP implementation rely on the system for day-to-day decisions.

2.7.2.2.7 Better ability to meet volume/product change

According to Sum and Yang (1993) and Sum et al. (1995), a better ability to meet changes of the products and the required volumes is one of the benefits obtained from MRP implementation. In this connection, Strzelczak (1995) argues that the most important quality for the MRP users is its flexibility which enables fast, smooth, and effective reaction to dynamic changes of the market demand. Figure 2.8 shows the old and the new expectations from MRP systems:

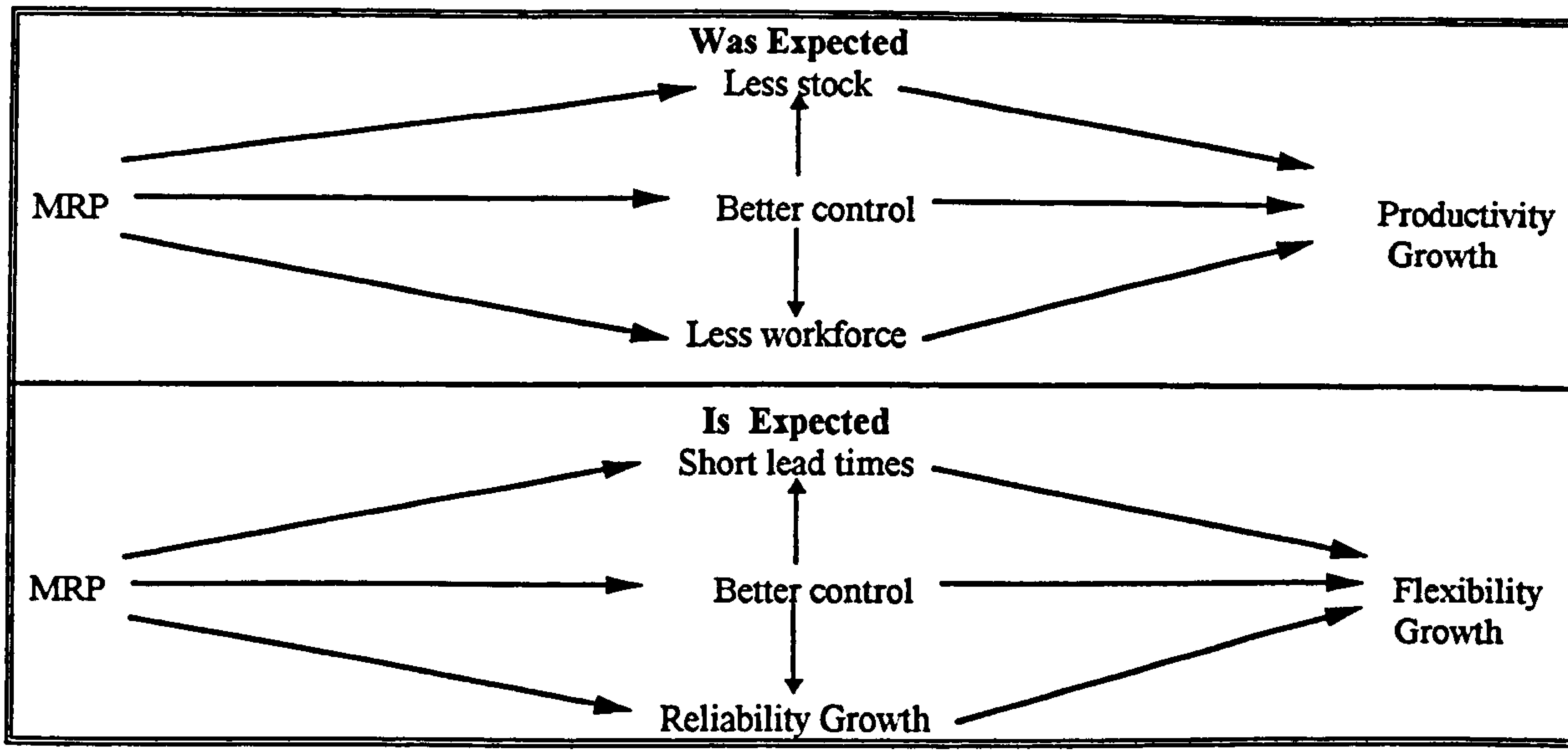

Figure 2.8 The old and new diamond of expectations from MRP systems (Quoted from Strzelczak, 1995: P.138).

2.7.2.2.8 Better production scheduling

According to Donk and Dam (1994) there are two possibilities for improving scheduling. The first is to implement one the large number of software packages available to support scheduling such as MRP software, and the second is to solve the scheduling problem by mathematically-oriented scientists. With an MRP system, the company can obtain a better production scheduling because it can generate a valid schedule to ensure making products on schedule and shipping on time (Schroeder et al., 1981; White et al., 1982; Duchessi et al., 1989; Sum and Yang, 1993; Sum et al., 1995). In other words, with an MRP system a company can achieve actual production schedules (Callarman and Heyl, 1986).

2.7.2.2.9 Reduced safety stock

According to Dilworth (1993) companies maintain safety stock for end items because they experience independent demand, which is subject to uncertainties. But one of the main outputs of an MRP system is manufacturing activity schedules indicating which items are to be manufactured, in what quantity and by what date (Wild, 1996). This will reduce finished goods and work-in-process inventories and maintain safety stocks at lower level. Moreover, Buzacott and Shanthikumar (1994) have concluded in their study about safety stock versus safety time in MRP controlled production systems that safety time is preferable to safety stock if there is a good forecast of required shipments, while safety stock is preferable to safety time if the master schedule is poor because customers change their required shipments dates or companies cannot predict the mean level of demand.

2.7.2.2.10 Better cost estimation

Traditionally, cost of production consists of material costs, wages, depreciation/interest, and overheads (Per-lind, 1991, Browne et al., 1996). The MRP system can have a significant profitable effect on the cost structure of a firm as evidenced by the internal measures such as the reduction in the amount of inventory on hand and which results in increased inventory turnover ratios (Callarman and Heyl, 1986; Plossl, 1995), and also through planning the required work force (Dilworth, 1993).

2.7.2.2.11 Improved co-ordination with marketing and finance

MRP systems have planning techniques that improve communication both inside and outside the manufacturing companies. Co-ordination here refers to the integration between functions and sub-systems in order to constitute a unified information system within the organisation (Per-lind, 1991). Manufacturing companies that have implemented MRP systems have made major improvements in co-ordination of cross-functional activities to produce the right material in the right quantity at the right time (Martin, 1995).

Ho stated that "MRP generates the information required to co-ordinate various activities in departments: telling people what to do and when to do it. Detailed instructions are conveyed to the factory floor indicating how people should respond under every eventuality" (1996, p.93).

Furthermore, Westbrook (1995) reported that lack of communication (the failure to involve other functions such as: marketing and purchasing), and poor training/education on MRP have been considered some of reasons behind the failure of computers such as MRP systems in manufacturing operations management.

2.7.2.2.12 Improved ability of job performance

Turnipseed et al. (1992) reported that 80% replied that their job would be more difficult or much more difficult without MRP and 81% of respondents reported that an MRP system has improved or significantly improved their ability to perform their job. Moreover, MRP systems provide a massive amount of information which may enable people in many departments within the company to plan and operate with greater coordination and effectiveness (Dilworth, 1993). For instance, purchasing can achieve improved vendor relations and better utilisation of time; the marketing department can achieve better customer relations through more reliable delivery; and the finance department can improve planning control (Elkhouly, 1994).

2.7.2.2.13 Reduced informal systems

With the implementation of an MRP system the amount of formalization is increased (Callarman and Heyl, 1986), whereby management must re-evaluate its method of conducting business through developing and instituting formal policies which describe how to perform business functions (e.g., forecasting, master scheduling purchasing etc.), procedures which describe how to enter and confirm associated system transactions, and responsibilities which should be distributed across functional areas (Duchessi et al., 1989). On the other hand, after MRP implementation a new formal structure breeds a new informal system. The success or failure of MRP depends considerably on how the new informal system responds to the needs of its members (Safizadeh and Raafat, 1986). In this connection, Jacobi (1994, p.13) states:

> "MRP is a formal and disciplined management process to plan and control the total resources of a manufacturing business to effectively allocate limited resources to the most profitable opportunities and produce predictable performance."

Moreover, Sandeep (1992) argues that the implementation of an MRP system leads to the birth of a so called "formal system" because lot sizes and order points are determined precisely using formal rules such as lead time off-set, and ordering rules etc. In the aggregate, Duchessi et al. (1989) reported that the successful companies with MRP implementation had developed formal controls, distributed responsibilities, and assured accountabilities i.e. defining what is expected from the organisation or people part (Sheldon, 1994) more than less successful companies.

2.7.2.2.14 Increased BOM/inventory/MPS accuracy

There are two opinions regarding BOM/inventory/MPS files accuracy: first, it is a critical factor affecting the implementation of MRP systems, second, it is one of the main benefits obtained from MRP implementation (Anderson and Schroeder, 1984; Callarman and Heyl, 1986; Sum and Yang, 1993). However, one can say that MRP is intentionally designed to bring accurate and timely information into the production operations (Safizadeh and Raafat, 1986). Many researchers have reported in their studies that data accuracy was increased as a result of MRP implementation. For instance Duchessi et al. (1988) report that the successful companies with MRP implementation had higher levels of data accuracy after implementation Smith et al., (1980) report that MRP implementation increased inventory accuracy from 75% to 90% in the company's Smith Valve. Also Sheldon (1994) reports that data accuracy in the stockroom was increased from 66% to 95+ percent in about 16 months after implementing MRP system at Raymond Corporation in upstate New York.

2.7.2.2.15 Improved morale in production

As pointed out by several writers such as White et al. (1982) and Sum et al. (1995), improved morale in production can be regarded as one of benefits obtained from MRP implementation. According to Cox and Clark (1984) as the implementation of MRP system increases, management's confidence in the system increases, and better co-ordination among departments is approved. Moreover, it ensures that all people are focused on the same final objective and are working toward common goals (Sheldon, 1994), "everyone knows the steps that they must perform and they can see the forest for the trees" (Hollander and Mirlocca, 1994), hence conflicts are few and can be resolved. This is reflecting in improved morale in production. Again, Schroeder et al. (1981) reported that improved morale in production is one of benefits obtained from MRP system by the American users.

2.7.2 The key failings of MRP systems

Despite MRP systems can be seen as an adequate successful venture, there are several qualifications to that success (Browne et al., 1996). They reported that MRP systems still have many faults such as a) MRP did not attempt to address the design of the manufacturing process. This leads to a situation where activities take place unnoticed (which are counterproductive to good manufacturing practice and hence to manufacturing system performance). For example, the BOM concept tended to encourage the development of many process stages, each with buffers separating them from the next stage. Now, this is not required because MRP structures seem to guide users in this direction, b) in the development towards MRP II, MRP I has perhaps sought sophistication but achieved complexity instead, c) the idea of leaving the capacity management to the user has never worked very well. Therefore, even today, the master planning level of MRP II is never really adequate on this account, d) MRP II has grown too large. It has tried to address too many problems in too many domains with the same basic approach. Fore example, now the shop floor control module of MRP II is not a viable alternative for complex manufacturing environments. The BOM concept may have had too much influence on the design of shop floor routings, and the result is the lack of clarity in representing manufacturing process routings, e) although the fact that lead times cannot be predicted, this does not necessarily imply that the average lead times cannot be used for planning purposes. MRP II companies use the average actual lead time for the planning lead time, through the application of the rough cut capacity *what if* analysis (RCCP). As a result, mistakes may happen if the user tried to drive operational control or production activity control with planned lead times, and f) the MRP approach to lot sizing is criticised. It seems that the MRP always favored simplicity in lot sizing or, indeed, no real lot sizing, by matching planned orders exactly with net requirements.

Sheridan (1995) adds that although MRP II systems have long played a role in integrating such corporate functions as sales and marketing, manufacturing, finance, and purchasing, the scope of user access tended to be rather limited, particularly in Management Information Systems- MIS controlled mainframe environments.

In practical terms, Greenhalph (1991); Zhao and Lee (1993) and Browne et al. (1996), discussed that there are several problems associated with MRP systems such as: a) the issue of schedule instability of MRP systems (i.e. significant changes in master production schedule including changes in quantity or timing of planned orders or schedules receipts) has been considered as a major concern for MRP practitioners, b) master production scheduling and production activity control are not computerised by MRP users as far as expected, c) capacity requirements planning has a relatively low utilisation by MRP users, d) it is assumed that the required materials for the master production schedule are either currently available or are not able to be supplied on time.

This may lead to excessive raw materials, namely increasing inventory depending on the procurement lead-time and the actual sales and production, e) several items within MRP system (such as lead times, safety stocks, and lot sizes) are supposed to be fixed when they are variable, f) if load exceeds capacity, MRP does not adjust schedules (Gupta, 1997), g) most of today's MRP and MRP II fail to allow any employee from any department to connect with the computer and get a picture of the status of any customer order (LaPlante, 1994), and h) MRP system can't tackle the problems encountered on the shop floor because they lack the responsiveness needed to coordinate the many simultaneous events occurring in a manufacturing environment (Gumaer, 1996).

However, applications of MRP II will continue to get richer, adding more functionality and more areas of the business. Therefore, recent attempts to re-name it (i.e. enterprise resource planning - ERP or customer- oriented manufacturing management systems - COMMS) without really changing its nature have received little acceptance (Turbide, 1995).

2.8 Factors that influence MRP suitability and success of MRP implementation

The previous section dealt with the expected potential and the real benefits obtained from MRP implementation. This section is intended to review the literature and the previous studies concerning factors affecting a) MRP suitability and b) success of MRP implementation.

2.8.1 Uncertainty factors

A review of the literature reveals that only one article, by Puttick (1987), has dealt with the impact of the degree of uncertainty on MRP implementation. He adds when the degree of uncertainty is high that direction is required to manage the uncertainty and control the whole operations by systems such as MRP. This will help it to keep track of all components and batches manufactured at different locations within a factory. Furthermore, he suggested that the uncertainty may arise from the unpredictable behaviour of customers and suppliers outside the business- the uncertainty of the marketplace (i.e. product variety, sales volume, and quality) and also it arises from unpredictable behaviour of people and unreliable plant within the company walls (i.e. plant availability, and absenteeism). The previous mentioned is discussed in detail as follows:

2.8.1.1 Product characteristics diversity

According to Puttick (1987) and Wild (1990), when product variety increases, the degree of uncertainty will increase. A company can meet that by modifying the production lines (Gerwin and Kolodny, 1992). The implementation of an MRP system can be seen as a way to manage the uncertainty, because it can perform the massive data processing required to plan every component in hundreds of products to be produced over a lengthy horizon. Consequently it improves the company's ability to react to changes in diversified customer orders (Dilworth, 1993).

2.8.1.2 Amount of aggregate product demand

According to Gerwin and Kolodny (1992) the amount of aggregate product demand can be regarded as source of uncertainty and which is reflected in changes in company's market share. They added that manufacturing companies can reduce this uncertainty by having the flexibility of volume. Therefore, it was thought that the implementation of an MRP system can be seen as a way to help company in order to reduce market share uncertainty or the volume uncertainty because its implementation may increase the company's ability to react to changes in customer orders, namely improving fitness to meet changes in market need (Dilworth, 1993).

In general terms, the uncertain demand works out in two cases- the first when the actual demand is higher than that forecast, on-hand inventory is lower than that projected, in turn an open order may be rescheduled to an earlier date during replanning, and the second when the actual demand is lower than that forecast, on-hand inventory is higher than that projected, in turn an open order may be rescheduled to a later date during replanning (Kadipasaoglu, 1995).

Moreover, Sandeep (1992) pointed out that in practice a mismatch between planned demands and actual customer orders causes order reschedules. Consequently, MRP system is required to match planned demands and actual customer orders and which makes the MPS realistic and stable.

2.8.1.3 Machine down time

It was suggested by Gerwin and Kolodny (1992) that machine downtime represents one of the sources of uncertainty in process operations. Per-lind (1991) found that the main reason for production stops within the biggest automobile company in Egypt (NASCO) is machine breakdown. This will be reflected in the company's inability to meet customer due dates. Therefore, the implementation of MRP system is necessary in order to achieve better delivery performance, namely cut delivery lead times in turn making promises kept (Callarman and Heyl, 1986; Dilworth, 1993).

2.8.1.4 The standards of raw material

Gerwin and Kolodny (1992) reported that meeting the required standards of raw materials can be regarded as source of uncertainty, and this is reflected in product quality. Therefore, the implementation of MRP system can be seen as a way to reduce uncertainty through providing just sufficient material just-in-time for subsequent operations to proceed, to provide a powerful capability for production review as much detail as possible, and to provide valid day-to-day schedules (Leng, 1987). This may be reflected in improving quality through increasing the production capability to produce items without defects (Dilworth, 1993).

2.8.1.5. Behaviour of people within the factory

One of the measurements of the uncertainty is that behaviour of people within the factory is unpredictable (Puttick, 1987). He suggests that when the rate of absenteeism is unpredictable the implementation of MRP system is required to control the operations, as the system provides a picture of work force planning, and can also achieve better utilisation of human and capital resources (capacity). For instance information from it will show the need to delay on some components if other wanted components are not at hand (Dilworth, 1993).

2.8.1.6 Reliability of plant within the factory walls

Puttick (1987) suggests that when the plant within the factory wall is unreliable the degree of uncertainty increases, in turn the implementation of MRP system may be required in order to translate the overall plans for production into individual steps necessary to accomplish those plans (Vollmann et al., 1992). In other words MRP system determines the quantity of materials need to support the MPS which determines how many products should be produced and when, depending upon the data derived from strategic, business and production plans. Therefore, when these data are reliable the degree of uncertainty concerning the MPS outputs is decreased. In this connection, Earl (1996) reports that business plans should be analysed to recognise where information systems such as MRP systems are most required.

2.8.1.7 Capacity constraints

Though the planning of production assumes that sufficient production capacity is available, the uncertainty in production capacity can be regarded as one of the difficulties in planning and control of production (Per-lind, 1991). Production planning and control system such as MRP system may can be seen as a way to reduce uncertainty through identification of actual capacity constraints (Dilworth, 1993), and working to fit between planned and actual capacity (Per-lind, 1991). Therefore, MRP I system assumes that no capacity constraints on the production of the master scheduled item and its components; all purchased materials are available (Lin et al., 1994), namely it assumes unlimited capacity in all work centres (Aggarwal, 1985).

2.8.2 Organisational factors

As pointed out by several writers such as Duchessi et al. (1988) and Sum et al. (1995) the organisational factors such as company's age; company's size; type of manufacturing system (Make to stock or make to order or both); manufacturing process; company's complexity; organisational arrangements; organisational willingness; and type of industrial process (layout) can be not only seen as determinants of MRP implementation but also as determinants of MRP benefits.

2.8.2.1 Company's age

According to Sum and Yang (1993), when the company becomes more aged and more established, it is more willing to invest in longer term enhancement projects like MRP systems. Other empirical explanations for the association between the company age and the implementation of MRP system have been offered by Duchessi et al. (1988) who conducted a survey regarding determinants of success in implementing material requirements planning (MRP) on 272 MRP companies in the US. They found that the average age of companies that have implemented MRP I/MRP II systems in the US is 37 years. In direct contrast, Sum et al. (1995) found in their study that there is no significant relationship between company age and the benefits obtained from MRP implementation.

2.8.2.2 Company's size

It is general believed that the company size has a great impact on the implementation of MRP systems. Anderson et al. (1982) and Sum & Yang (1993), indicated that as companies increase in size as measured by gross sales, they have a greater inclination to implement MRP systems. Sum et al. (1995) in their study about the analysis of the MRP benefit-determinant relationships for 128 companies in Singapore found that there is a positive (+) followed by negative (–) relationship (using ACE technique) between company size (measured by gross sales, number of employees, current and additional investment over next 3 years in MRP) and operational efficiency (measured by improved productivity, improved quality, increased throughput and reduced inventory costs). Cerveny and Scott (1989) reported in their study regarding MRP implementation in 433 companies in the US, that there are significantly more MRP systems in large companies (measured by number of employees, sales and number of product lines).

Moreover, White et al. (1982) employed multiple discriminate analysis to examine the impact of several variables such as company size, management support, etc. as a predictors of the successful implementation of MRP system within 357 companies in the US. Though they found that company size did not show significant discriminatory power, there is an impact of company size on the successful implementation. This is embedded in another two variables which are highly correlated with company size, namely the length of time of implementation and the degree of computerisation. The analysis revealed that the two variables have a great impact on the successful implementation. Again, Burns et al. (1991) in their study regarding critical success factors in manufacturing resource planning implementation on 502 companies in the US, found that MRP companies have been characterised by more employees, greater annual sales and more end items than companies who did not use MRP II. Schroeder et al. (1981) found in their study regarding MRP benefits and costs in 679 MRP companies in the US, that there is a positive (+3.8)[2] relationship between company size and the number of expediters. They reported that large MRP companies had more expediters.

2.8.2.3 Type of products

As pointed out by several writers such as Anderson et al. (1982); Duchessi et al. (1988); Cerveny and Scott (1989); Cooper and Zmud (1990); Sum and Yang (1993) and Parker (1995), the implementation of MRP system is affected by the type of products that company offers to serve its customer.

According to Dilworth (1993) and Browne et al. (1996), there are four types of products or marketing strategies based on a distinction between stock driven or customer driven systems. Customer driven production system can meet customer needs quicker than the other or can respond faster to changes due to a direct interaction between customer and manufacturer is very high (see Figures 2.9; 2.10 below).

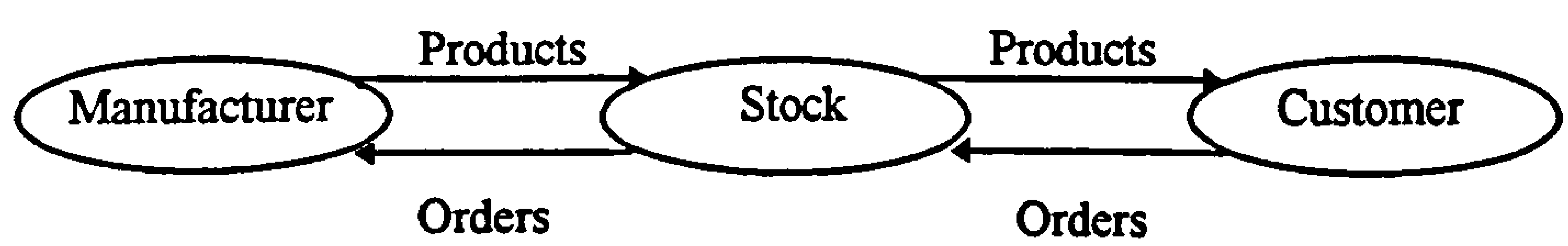

Figure 2.9 Stock driven production (Quoted from Browne et al., 1996, p. 16)

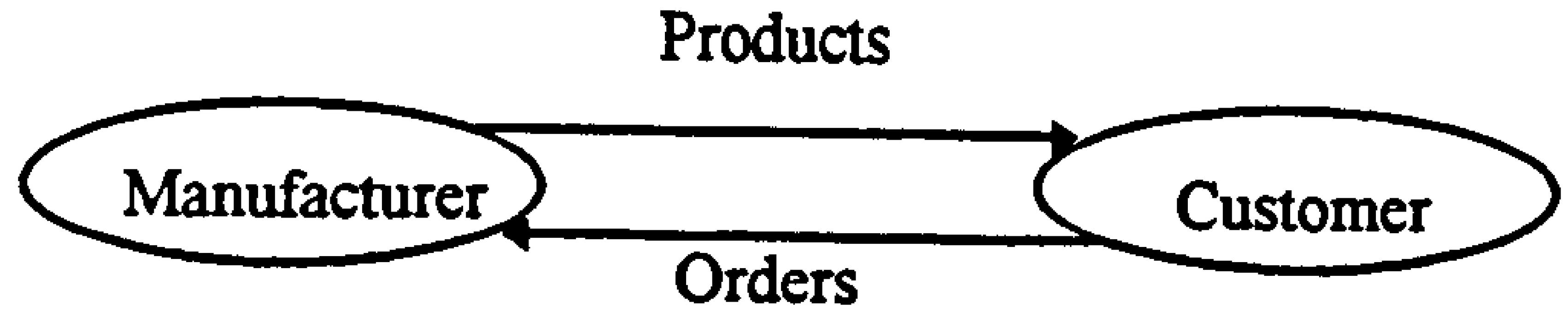

Figure 2.10 Customer driven production (Ibid.)

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[2] Using T-test.

These types of products are as follows: a) Make -To- Order (MTO) describes a manufacturing system where the products are selected by customers in advance (e.g., based on a catalogue), and then the company completes the end item required after receiving the customer order for the item, b) Make -To- Stock (MTS) describes a manufacturing system where the demand for clearly defined product is very well known and predictable. The company makes items that are completed and placed in stock before receiving the customer order, then the end items are shipped "off the shelf" from finished goods inventory after receiving customer order. In general, direct interaction between the manufacturer and the customer tends to be very low, c) Assemble-To- Order (ATO) describes a manufacturing system where products are configured or assembled to customer order from a set of assemblies and components such as an automobile factory, d) Engineer-To-Order (ETO), describes a manufacturing system where the customer order requires that a new engineering design be developed because the item is unique. In general, the product is designed to a customer specifications (custom-designed item).

In sum, many companies are now moving towards using a hybrid strategy in order to achieve a higher degree of customer satisfaction. And also, it is notable that moving from MTS to ETO depends on what the literature called Customer Order Decoupling Point (CODP) which defines the parts of the process that are driven by customer orders and the parts that are driven by forecasts (Browne et al., 1996).

According to Anderson et al. (1982); Cooper and Zmud (1989); Cerveny and Scott (1989) and Sum & Yang (1993), MRP systems are more frequently adopted by manufacturing companies that follow a combination of make to order and make to stock products strategy. Burns et al. (1991) reported that two-thirds of 502 MRP companies in the US produce products both to order and stock.

Sum et al. (1995) found that both types of manufacturing systems, namely Make - To- Order (MTO) or Make -To- Stock (MTS) impact on the benefits obtained from MRP regarding customer service, but it is being in Make -To- Order (MTO) environment more than Make -To- Stock (MTS) environment.

Schroeder et al. (1981) reported that the type of products had some impact on two performance measures. The inventory turnover was more frequent in make-to-order companies than make-to-stock companies, while the later one had lower delivery lead times than the former.

2.8.2.4 Type of manufacturing

According to Lockyer et al. (1989); Dilworth (1993); Kim and Lee (1993) and Browne et al. (1996), there are several types of manufacturing (sometimes called the production systems) such as: project manufacturing, job shop manufacturing, repetitive manufacturing, batch manufacturing, and continuous manufacturing.

Plossl stated that:

> "It is clear that the application of MRP is generally better in discrete order as contrasted to continuous processing and repetitive manufacturing, where specific batch orders may not exist, and for complex rather than simple, even one-piece, products" (1995, p.54).

Anderson et al. (1982) reported in their study about Material Requirements Planning Systems (MRP I): the state of the art in 679 manufacturing companies in the US, that 83.2% of companies that have implemented MRP system are working in assembly and fabrication operations environment. In the same way, Sum and Yang (1993) found that MRP systems have been implemented by Singaporean manufacturing companies that work more in assembly and fabrication operations environment than companies that work in assembly only or continuous/process flow environments (33.9:28.8:13.6).

2.8.2.5 Company complexity

The company becomes complex when its products are with many components that must be identified and controlled, there is a large number of workcentres, the number of levels in bill of materials is large (Puttick, 1987), the number of products is large, there are dependencies between different production lines and the company has to produce a combination of make to order and make to stock (Donk and Dam, 1994). If so, the implementation of MRP system is required to control the entire operations and to keep track of all components.

Sum and Yang (1993) reported MRP systems are more often adopted by manufacturing companies with a complex product structure and which is measured by number of items (it indicates the size of the product structure), number of levels in bill of materials (it indicates the depth of the product structure) and the degree of commonality of parts (it measures the average number of the present of parent items for each component item). Furthermore, Burns et al. (1991) found that MRP companies have been characterised by more components, and more level of bill of material than companies did not use MRP II.

Schroeder et al. (1981) found that there is a relationship between the complexity of the product structure (measured by number of parts & components, and level in the BOM) and the successful implementation of MRP systems measured by the five performance measures (i.e. increased inventory turnover, decreased delivery lead time, increased delivery promises percent, decreased split ordered, and decreased number of expediters). They reported that companies with more parts and components were poorer in their performance, while companies with more levels in the BOM had better performance.

2.8.2.6 Organisational arrangements

Top management has to control and steer the MRP project by influencing its progress. To do this, a steering committee should comprise the company president, and vice president of the various department such as executive vice president operations, vice president finance, director, sales and marketing (Iemmolo, 1994). Furthermore, as pointed out by several writers such as Forster and Hsu (1976); Brenizer (1981); Savage and Schuette (1982); Pendelton (1982); Huther (1983) and Anderson & Schroeder (1984) the successful implementation of MRP system depends upon the organisational arrangements accompanied the implementation. These arrangements include the forming of a steering committee and project team, and having these committee meet regularly on weekly or monthly basis, having someone with authority on the steering committee. These reflect organisational and managerial support which is necessary to generate acceptance of MRP within the organisation and foster user involvement.

Duchessi et al. (1988) found that nearly two-thirds of both successful and less successful companies reported forming a steering committee, that the steering committee met at least once a month, and the project team met weekly. They add that the successful companies were much more likely to agree that someone with full authority attended steering committee meetings.

According to Burns et al. (1991), the data collected from 238 MRP companies responding to the survey indicate that a steering committee was formed from manufacturing materials, production and inventory control, and data processing departments in 83% of companies. The project managers had full-time responsibility for managing the project in 40% of MRP companies.

Furthermore, they found that 83% of MRP companies used a project team which consisted of eight members from manufacturing materials, production and inventory control, and data processing departments and which often met on a weekly basis. In addition, they reported that the use of a project team was strongly linked with the stage of MRP II implementation achieved, and also found that the more time devoted by project manager to the effort of implementation, the more advanced stage of MRP implementation.

2.8.2.7 Type of process (layout)

As mentioned earlier there are several types of production systems within manufacturing environment. Each production system describes something about its manner of operation, (i.e. the facility, the equipment, and operations methods that company uses based on the type of products that it provide to its customer). This reflects the way that company arranges departments, machines, storage areas, and so forth, within the confines of some physical structure such as a factory, a warehouse, a retail store, or an office (Johnson et al., 1974). In this connection, Wild (1996) defined the layout by the arrangement of facilities in a given space. The need for layout is a) to facilitate the movement of materials, components, the finished products, and labour and which is reflected in a reduction of the distance moved by items and in the time consumed, and hence in the cost, b) to achieve a reduction in work in progress and hence reduce throughput time and c) to utilise of space, facilities of operation, maintenance, supervision and labour.

In general, there are three types of layout; firstly, layout by product which is used when the entire production process is devoted to a single product or activity. It is also called a layout by continuous process or by assembly line. Secondly is layout by process where activity areas are arranged to group all work stations of a given type together. It is also called a layout by job shop, and thirdly is layout by a combination between product and process (Johnson et al., 1974; Dilworth, 1993).

Anderson et al. (1982) and Sum & Yang (1993), reported that MRP systems are more adopted by manufacturing companies with the complicated processes (layout). They have been implemented in assembly line and job shop more than continuous process environments. While, Burns et al. (1991) found that 32% of manufacturing companies with job shop manufacturing have implemented MRP systems, followed by 29% of MRP companies with repetitive production and 10% of MRP companies utilised a continuous process. Moreover, Cerveny and Scott (1989) found in their study that MRP users are more likely to be assembly line or combination of process types than nonusers. Furthermore, Duchessi et al. (1988) reported that 51% of MRP companies in their sample are discrete/jobshop, followed by 29% of companies working within repetitive manufacturing environment.

2.8.2.8 Organisational willingness

According to Kneppelt (1981) the major problem that impedes the implementation of MRP II is the need for a higher degree of efficient integration of the human element. Wacker et al. (1977), argue that the success of MRP implementation lies in its acceptance by the people of the organisation. This acceptance is subject to resistance from those people partly because they may expect that the implementation of MRP system will formalise many decisions that were left to the individual's discretion, will cause the informal system to be more accountable, will cause changes in duties and job descriptions, will create perceptual problems over what its purpose is, will require learning new methods or because it is a complicated dynamic system.

Burns et al. (1991) found that 49% of MRP users may resist change and go along with changes only if forced to comply, and only 21% of MRP companies may actively seek change. Also, they found the organisation's willingness to change was associated with the stage of implementation and the more willing an organisation is to change, the more successful implementation.

2.8.3 Implementational factors

As was mentioned in an earlier part in this chapter MRP has been the most widely implemented system over the last three decades. A review of the literature reveals that there are several factors affecting the implementation process of MRP system itself such as length of time since implementation; implementation strategy; initiator of MRP effort; vendor support; and implementation problems.

2.8.3.1 Length of time in implementation

The length of time since MRP implementation has been found to be a reliable discriminator of successful and unsuccessful implementation (White et al., 1982). Thus, according to Sum et al. (1995) companies with matured systems tend to offer higher customer service benefits (i.e. better meeting of delivery promises, shorter delivery lead time, better production scheduling, and better ability to meet volume/product change).

The positive impact of a matured system on MRP benefits could be explained by it taking time to achieve effective coordination among different departments such as marketing and production, and also by greater user acceptance of the system as a result of prolonged usage.

2.8.3.2 Implementation strategy

The conversion to an MRP system can be defined as a change from one situation to the other. It has been seen as a bridge which takes form, length, width, supporting structure, materials... depending how wide the river, the anticipated traffic and so on (Forster and Hsu, 1976).

In general terms Badiru and Schlegel (1994) present four strategies can be used for technology conversion:

- Parallel conversion: both technologies (new and old) operate concurrently until there is confidence that the new technology is satisfactory.

- Direct conversion: the old technology is removed totally and the new technology is implemented. This can be used in case of the two technologies cannot be kept operational for incompatibility or cost considerations.
- Phased conversion: the modules of new technology are gradually introduced at a time using either direct or parallel conversion.
- Pilot conversion: the new technology is fully implemented on a pilot basis in a selected department within the company.

Croke (1985) and Bessant (1991), advocate that phased conversion can be regarded as the right way of implementing a new technology such as CAPM technologies within manufacturing companies, where users become more experienced with the process of time.

Burns et al. (1991) found that 80% of MRP implementation was based upon a phased approach, with an average of four phases required to complete the implementation.

Plossl (1995) and Browne et al. (1996) argue that one of the problems of MRP implementation is that MRP users involved in the implementation process do not have a clear understanding of the approach to implementation.

2.8.3.3 Initiator of MRP effort

According to Sum and Yang (1993), "initiator of MRP" means that person or department which can effect the extent and rate of acceptance of the system in a company. White et al. (1982) report that there are several initiators of MRP systems such as top management, production and inventory control management, both top management and production and inventory control management, data processing personnel, and software/hardware vendors. Sum and Yang (1993) found that top management were committed to introducing MRP systems in 67.8% of MRP companies in Singapore. In contrast, White et al. (1982) found that 31% of MRP system were introduced by production and inventory control (p&ic) management, and also, both top management and p&ic management were committed to introduce MRP system in 31% of MRP users in the US.

In general terms, it has been found to be a critical factor for the successful implementation of new manufacturing technology (Chen and Small, 1994). As pointed out by several writers such as Wight (1981); Donovan (1982); Beddick (1983), Dilworth (1993); Sum et al. (1993); Ang et al. (1995) and Browne et al. (1996), top management commitment is regarded as a prerequisite for a successful MRP implementation.

To reap the benefits of MRP system, top management has to be committed to work out and maintain a new set of values in the organisation so that it can operate effectively. Furthermore, with top management support the people tend to accept changes (Blackstone and Cox, 1984). Thus, to increase the opportunity of success in implementing MRP system, top management has to effectively support and be involved in planning, implementing and monitoring of the systems (Cox et al., 1981). Despite this, getting top management support is not an easy task (Ishman, 1995). The question is how top management are committed. The answer is they must become involved in the implementation, set clear goals for the implementation, use formal planning and control functions of MRP/MRP II to run the business and measure results, distribute responsibilities across functional areas, allocate resources to training during the modernisation phase, and hold people accountable, namely that they know what is expected from them (Duchessi et al., 1989; Sheldon, 1991;1994; Chen and Small, 1994). Furthermore, Schroeder et al. (1981) found in their study that top management support affected percentage of delivery promises that were met and percentage of split orders.

2.8.3.4 Data accuracy

According to Anderson et al. data accuracy means "the accuracy of information with which management deals" (1982, p.62). Macbeth and Ferguson (1994) consider that both MRP I and MRP II are so dependent on accurate data that extensive shop floor recording equipment's need to be installed to automate the stock and material information movement. Duchessi et al. (1988;1989) had concluded that data accuracy is a major determinant of MRP implementation success. In the same way Sum et al. (1995) found that the degree of data accuracy, whether it was planning data such as inventory records data or execution data such as shop floor data, impacts on all benefits to be obtained from MRP implementation (i.e. operational efficiency, customer service, and coordination benefits).

Ang et al. (1995) found in their study that data accuracy represents the most important factor affecting the successful implementation of MRP systems in Singapore. They found that the accuracy of BOM records, inventory records, manufacturing lead times, and master production schedules were rated as especially significant. Moreover, Wight (1983;1989) and Blackstone & Cox (1985) reported that 98%-100% of the bill of materials, 95%-100% of the inventory records, and 95%-100% of the routing file should be accurate before MRP implementation.

On the other hand, it is generally believed that inaccurate data will undermine management decision making ability which has a negative effect on all organisational aspects. And also inaccurate data records such as BOM file and inventory records may cause great confusion and uncertainty about MRP system output necessary for the effective manufacturing management (Westbrook, 1995). This will reduce productivity contrary to the initial objective of MRP implementation.

Other theoretical explanations for an association between data accuracy and the successful implementation of MRP system have been offered by several writers such as Vollmann et al. (1992); Dilworth (1993) and Browne et al. (1996). They consider the successful implementation of MRP system depends upon the degree of data accuracy of the basic data files such as inventory records which are established and maintained for inventory item (Plossl, 1995). Its inaccuracy will lead to the generation of wrong net requirements. With the use of MRP system these requirements will be rapidly exploded through lower levels of components (i.e. BOM) to generate production and purchase orders that are of the wrong quantities. Bill of material records which show the structure of products (i.e. it includes data regarding component part numbers required to make each individual part, number of each required, units of measure and engineering change numbers) will result in similar outcome if it is inaccurate (Vollmann et al., 1992).

The failure of an MRP system may be due to the bad data in use e.g., BOM/ Inventory/ lead times data, because the value of MRP depends on the quality of data it uses (Plossl, 1995).

Moreover, Schroeder et al. (1981) found in their study that data accuracy has a positive effect on the percent of delivery promises that met.

2.8.3.5 Vendor support

According to White (1980) and Keen (1981), outside assistance such as vendor support is critical to the successful implementation of any major organisational change such as an MRP system. Management must assure that continuous support throughout the implementation is provided by the software vendor (Duchessi et al., 1989).

Cerveny and Scott (1989) reported in their study that 61% of 261 MRP companies received help from their system vendor. Also, they found that there is a positive relationship between the amount of outside help and some benefits obtained from MRP implementation for instance, inventory turnover ratio (sales/inventory) increase (+.50) and lead time decrease (+.24).

Ang et al. (1995) reported in their study that vendor support has been considered as a significant factor affecting the successful implementation of MRP system in Singapore.

Duchessi et al. (1989) reported in their study about implementing a manufacturing planning and control information system on 272 manufacturing companies with MRP I/MRP II software in the US that successful companies reported fewer problems with vendor support, greater understanding of the instructions of software product, lack of vendor software support, vendor provision of the conversion of data into the new system, and were more likely to agree that vendor personnel efficiently resolved software problems. In sum, Duchessi et al. (1988) cite having software and hardware vendor support as a significant element of the successful implementation of an MRP system.

2.8.3.6 Implementation problems

A review of the literature reveals that there several factors which may cause obstacles or problems which manufacturing companies may encounter during the implementation of MRP systems.

Duchessi et al. (1988;1989); Groves (1990); Sum and Yang (1993) and Browne et al. (1996), consider lack of support of people or departments, such as lack of support from top management, lack of support from production, lack of support from supervisor/foreman, lack of support from marketing, and lack of support from finance. These are very significant barriers encountered in the implementation of MRP system.

Ang et al. (1995) concluded in their study that the most common problem encountered in the implementation of MRP systems in Singapore is that an MRP system is expensive. 25 out of 52 companies that have implemented MRP systems in Singapore have invested more than S$ 500.000 into the system. Leng (1987); Plossl (1995) and Browne et al. (1996) argue that lack of clear goals for MRP effort represents one of the barriers to MRP implementation because MRP users do not comprehend the main goals for MRP implementation such as meeting of delivery dates and a reduction in inventory.

Duchessi et al. (1988) reported that less successful companies reported a lack of involvement from vendor. While Sum et al. (1995) consider that lack of vendor knowledge on MRP one of the problems which are encountered in implementing MRP systems.

Beatty and Gordon (1988) reported that one of the barriers to implementation of A.M.T such as computer aided design and computer aided manufacturing is in compatibility of systems and which stems from purchasing a variety of hardware and software. While White et al. (1982) reported that the problem with lack of suitability of hardware and software has a negative impact on the successful implementation of MRP systems. Hollander and Mirlocca (1994) reported that management must choose software that most closely fits its requirements and leads to an easy installation. Duchessi et al. (1989) add that companies with successful MRP implementation reported that there is no problem with the suitability of hardware and software. Moreover, it is interesting to mention here that implementing an MRP system is totally different from installing a TV set. To implement an MRP system three areas should be understood: functionality (i.e. financial planning, using operating numbers, scheduling etc.), modifications (i.e. need for customised reports, monitor screen display etc.), and bugs which means that people have to learn that software operation is more of a hope than a reality (Leng, 1987).

Sum and Yang (1993) reported that lack of company expertise in MRP represents the biggest barriers to MRP implementation in Singaporean companies.

One of the barriers to MRP implementation is that manufacturing companies need long time to learn how to implement MRP systems. This time is ranged from two years (Smith, 1993) to 10 years (Voss, 1986).

Sum and Yang (1993) and Sum et al. (1995) consider lack of information technology expertise one of the obstacles that impedes the implementation of MRP systems by manufacturing companies.

In the aggregate, Covin (1981) reported that there are five categories for problems that may impede the successful implementation of MRP systems: a) computer system not technically sound, b) poor inventory records, c) poor bills of material and routing records, d) unrealistic master schedule, and e) personnel attitudes.

2.8.4 Technological factors

In simple terms "technological factors" is the label for those factors which relate to the source of the MRP system; the system's installation, its features and its development.

2.8.4.1 Degree of integration between MRP modules

Despite computerisation being the essence of the implementation of the MRP system process, the operational effectiveness of MRP implementation is measured not only by what MRP modules have been computerised and what is the degree of computerisation of them, but also what is the degree of integration among the computerised modules (Sum and Yang, 1993; Sum et al., 1995). In turn, the next subsections are devoted to shed some light on the two related issues, namely degree of computerisation and degree of integration among MRP modules.

2.8.4.1.1 Degree of computerisation

White et al. (1982) reported that degree of computerisation of MRP modules can be regarded as a significant discriminator of successful and unsuccessful implementation of MRP systems. The implication is that the higher the level of computerisation the greater appears to be the successful implementation of the MRP systems (Sum and Yang, 1993). They add that there are a wide array of MRP modules, but companies only install those that meet their requirements.

As put forth in numerous studies (Duchessi et al., 1988;1989; Sum and Yang, 1993; Browne et al., 1996), the basic MRP modules that must be implemented and integrated by manufacturing companies in order to ensure the successful implementation of MRP system include: a) the Bills Of Materials module which essentially is used in order to translate the master production schedule into subordinate components requirements (Vollmann et al., 1992); b) the Master Production Schedule module which " takes into account the sales forecast as well as considerations such as the backlog, availability of material, availability of capacity, management policy, and company goals, etc. in determining the best manufacturing strategy" (Browne et al., 1996, p132); and c) the Inventory Control module which is used to state every item to be controlled by MRP system (Dilworth, 1993), and which serves as an input to the master schedule.

In this connection Cerveny and Scott (1989) found that 235 of 261 MRP companies in the US had installed BOM and Inventory Control modules, and over 70% of them had installed Master Production Schedule module which is different from the MRP procedure whereas the demand will only generate from the scheduled MPS and not from the projected requirements. Consequently, the MPS will not influence manufacturing or purchasing orders without the intervention of the master planner (Browne et al., 1996).

To become more effective at manufacturing planning and control system, company requires to install a) a Forecasting module which is used in order to help the company to get a better handle on expected demand and inventory required to meet customer service objectives. It should account for the level (rate of demand per period), trend (rate of increase or decrease), and seasonability i.e. period fluctuations around the trend line (Duchessi et al., 1988; John, 1996); b) a Shop Floor Control module which can help manufacturing companies "to accommodate special order requests quickly and meet production demands proactively by allowing manufacturers to prioritise and manipulate day-to-day production activity" (Ross, 1997,p.90). It also, provides current status to the capacity requirements planning system as well as activity tracking to support input/output control (Kneppelt, 1981) and to "support dispatching and detailed scheduling control and allow line management to report current progress of open shop orders" (Duchessi et al., 1989, p.76), c) an Explosion of requirements module which explodes the requirements in MRP system from master production schedule down through component levels in accordance with the logical linkage of inventory records from top to bottom of bill of material structure (Plossl, 1995), d) Purchasing and receiving module which determines when and what parts should be ordered from vendors (Duchessi et al., 1989).

Furthermore, there is a wide array of sophisticated MRP modules would be required to make links to other major MRP modules (Frazer and Nakhal, 1992) such as: Capacity Requirements Planning, Rough-cut capacity planning, Financial analysis, Customer order service, Routing/work centres, Cost accounting, Sales order processing, Operations scheduling, Inventory Control module and Payroll/human resources.

2.8.4.1.2 Degree of integration

According to Carrie and MacIntosh (1993), the term "integration" is considered in many contexts and at many levels. However, there are two points of view concerning its accomplishment. The first the narrow view, relates to the coherence and coordination of elements within the computer systems and the second the wider view, is concerned with the coordination of activities and the suitability of the current systems in the organisation to achieve its objectives (Carrie and MacIntosh, 1992). They added that:

> "integration is achieved by the communication of, and adherence to, corporate strategic objectives throughout an enterprise, thereby allowing these objectives to dictate the real time operational activities of the enterprise" (1992, p. 162).

In general terms, MacIntosh (1994) define a hierarchy of integration, three type of integration, containing four levels:

- Technical: The use of compatible hardware and software data
- Information: The use of common data definitions and status information expressed in common currency
- Strategy: The existence of common aims at all levels within the organisation
- Functional: The merging of business functions

Sum and Yang (1993) and Sum et al. (1995), attempted to measure the degree of integration among MRP modules by use a simple scale (discrete scale)[3]. Sum and Yang (1993) reported a degree of integration of at least 60% in 65% of Singaporean users.

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[3] Their methodology has been used in the study (see Q. 28 in Appendix. A).

Moreover, Sum et al. (1995) found in their study that higher efficiency is accompanied by a higher degree of integration between MRP modules and also they concluded that high integration is needed to achieve effective coordination among subsystems and departments.

Furthermore, Miller and Sprague (1975) highlight the importance of coordination and integration between MRP modules in order to ensure the successful implementation of an MRP system. In the same way, Safizadeh and Raafat (1986) argue that the frustration with MRP hardware may stem back from a lack of integration of the MRP software modules.

2.8.4.2 Source of MRP system

As put forth in numerous studies (Duchessi et al., 1988;1989; Sum and Yang, 1993) there are several sources of MRP software package, a) developing the entire software package in-house, b) all bought-in as turn-key systems or off the shelf or customised, and c) bought-in and customised in-house.

Burns et al. (1991) reported that 59% of MRP users purchased software with some modification while only 29% had developed the software package for MRP in house. They found that the source of MRP II software was linked to MRP II success and positively associated with the stage of MRP achieved (i.e. D or C or B or A stage).

And also, Sum and Yang (1993) reported that 71.1% of MRP companies in Singapore source their software from vendors and only 13.6% developed the entire software in-house. They add that companies prefer to buy turn-key systems in order to shorten the MRP implementation time and also to take advantage of the consultancy offered by vendors.

The source of the MRP system has been considered as a technological factor affecting the implementation of such systems (Sum et al., 1995). White et al. (1982) found that there is a relationship between MRP implementation and the outside source of MRP system such as whether it comes from software or from hardware vendors.

Schroeder et al. (1981) found that there is an adverse relationship between the source of MRP software (software vendor) and the performance measures. They reported that where vendor supplied software with no or little or high modifications MRP companies had the poorer performance. Therefore, they suggest the best approach is to use vendor supplied software with some modifications not too much and not too little.

The computer hardware in MRP systems can run on microcomputers, mainframes or minicomputers. According to Diamond (1997) MRP I and MRP II were associated exclusively with mainframes and microcomputers. This trend has been changing, however, since the mid-1980s with the introduction of PC-based manufacturing applications. Moreover, Sum et al. (1993) found that about 49.2% of the MRP systems in Singaporean companies run on minicomputers while an equal percentage each (20.3%) run on microcomputers and mainframes. Finally, the maintenance of MRP can be done whether in-house or by software vendor or by IT specialists. In this connection, Duchessi et al. (1989) reported that the maintenance of MRP was completed by software vendor at a successful company with MRP implementation (Flo-Con company).

2.8.4.3 System installation costs

In general terms, Vollmann et al. (1992) argue that too many managers ask " How much does Manufacturing Planning Control system such as an MRP system cost?" because it can run from a few thousand dollars to millions. They add that the problem not with the cost of hardware and software of MPC system because it is decreasing dramatically and will continue to do so, but it is concerned with preparing people for operating a new system. They suggest that the cost of any MPC such as MRP system includes several categories of costs as follows: training cost (e.g., training trainers and system users, cleaning up the data base (e.g., developing the correct data), personnel expenses (e.g., full time and part time project members), support of people (e.g., revised pay schemes), relayout of facilities (e.g., factory floor changes), software (e.g., package purchase cost), and hardware cost (e.g., network in equipment).

As reported by White et al. (1982) and Ang et al. (1995) the cost of an MRP system can be regarded as one of the major problems that may encounter the implementation of MRP system. Fisher (1981) considers the cost of MRP system as an important factor for MRP implementation. This cost includes purchase price and operation & maintenance costs.

Sum and Yang (1993) reported that all MRP companies in Singapore were prepared to make further investment whether in order to extend or to change the current MRP system. Moreover, the cost of MRP system including the current cost and the further investment was regarded as a determinant variable of operational efficiency (Sum et al., 1995).

2.8.4.4 User Class

"User class" is a term used by Anderson and Schroeder (1982) to represent the stage of development of the MRP systems within manufacturing companies or the extent of MRP infusion within manufacturing companies based on A through D classification scheme suggested by Wight (1984;1989). Whereas Class D indicates that MRP companies have not achieved even the lower advanced stage of MRP implementation, they had only passed the adoption stage, while Class A indicates that MRP companies have achieved the higher advanced stage of MRP implementation. These classes are illustrated below:

Class A: A closed -loop system used for both priority planning and capacity planning. MPS is levelled and used by top management to the business. Most deliveries are on time , inventory is under control, and little or no expediting is done.

Class B: A closed-loop system with capability for both priority planning and capacity planning. In this case, the MPS is somewhat inflated, top management does not give full support, and some inventory reductions have been obtained, but capacity is sometimes exceeded, and some expediting is needed.

Class C: An order launching system with priority planning only. Capacity planning done informally, typically with an inflated MPS. Expediting is used to control the flow of work and a modest reduction in inventory is achieved.

Class D: The MRP system is 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.

Cooper and Zmud (1989) reported in their study about material requirements planning infusion on the random sample of 62 manufacturing companies in the US, that MRP is infused (D through A) when manufacturing method is more continuous than intermittent, and when production is more complex (measured by average number of parts and BOM levels).

Sum et al. (1995) found that MRP companies with more aged system (closer to class A) tend to provide higher customer service benefits (delivery promising, lead times, responsiveness to changing market demand, etc.).

Moreover, Schroeder et al. (1981) reported that user class had a very strong affect on all five types of performance. For instance, they found that MRP company with class A had achieved the best inventory turnover.

2.8.4.5 MRP system features

According to White et al. (1982); Anderson et al. (1984); Vollmann et al. (1992); Sum et al. (1993); Dilworth (1993) and Browne et al. (1996), the common technical characteristics of MRP system are:

a) Update method: There are two methods which can be used to update an MRP system, firstly regenerative MRP programs construct new data each time (usually each week). It views the MPS as a document, new editions of which are released on a periodic basis. The second is the net change MRP program which revises only the data affected by transactions that are put into it or by a new master schedule. These transactions may be entered into a net change program frequently to reflect conditions as they change. It views the MPS as a document in a manner of continuous change (Dilworth, 1993;

Browne et al., 1996). Furthermore, a combination between the two methods is possible. It was found in practice Regenerative programs may borrow some net change features and conversely, net change programs are used periodically just like regeneration programs (Plossl, 1995).

b) Use of cycle counting: It can be regarded as a necessity to achieve and maintain inventory accuracy. For doing that companies must learn that the purposes of doing cycle accounts are to find the cause of errors and not just to correct the inaccurate count, to maintain a high level of inventory record accuracy, and to correct statements of assets (Covin, 1981; Correll, 1995).

c) Use of pegging. This is a special feature of MRP systems which allows MRP users to trace an item's gross requirements to parent sources in the master schedule or identify the sources of demand for a particular component's gross requirements. If each individual requirement for a planned item is identified in the BOM this is termed single level pegging, while if it is identified against a master production scheduled item and /or customer order this is termed Full Pegging (Browne et al., 1996).

d) MPS update frequency: The frequency of updating and revision of master production scheduling is linked to the forecasting cycle in order to respond to changes in the customer orders and to serious unplanned developments in procurement. It is often weekly when computer forecasting models are used, but it may be monthly when management review the data (Plossl, 1995).

e) Allocation of inventory: This refers to the quantity of an item earmarked for a parent order released for production. Allocated parts belong to the parent orders but are still physically on hand in the stockroom because there is a gap between order release and issuing material from stockroom (Plossl, 1995). This a step before order launching that involves an availability check for the necessary component or components. It means that this amount of component part is mortgaged to the particular shop order and is, therefore, not available for any other shop order. If sufficient quantities of each component are available, the shop order can be created. If the order is created, then the system allocates the necessary quantities to the particular shop order (Vollmann et al., 1992).

f) Use of an automatic lot sizing: This has been considered as "the particular technique to determine order quantities for a given inventory item and to determine the requirements for its components" (Plossl, 1995, p.50). Several techniques can be used in order to help determine the appropriate lot size in MRP systems (Dilworth, 1993; Plossl, 1995; Browne et al., 1996). Some of these techniques are: The lot for lot (L4L) method, fixed order quantity (FOQ) method, the economic order quantity (EOQ) method, period order quantity (POQ) method, the wagner within algorithm (WWA) method, and least total cost (LTC) method. However, there is a problem related to selecting the proper technique for each item needed in the computer program that controls the requirements computation. But according to Browne et al. (1996) the user can choose the lot sizing technique which is easy to use in practice, easy for production people to understand, and efficient in terms of computing time.

g) Time bucket size: According to Browne et al. (1996) the time bucket refers to the units of time into which the planning horizon (i.e. the span of time the MPS covers) is divided. The data structures used to represent time in an MRP system can be bucketed or non-bucketed. In the bucketed approach, a predetermined number of data cells are reserved to accumulate quantity information by period. This is depicted by the matrix structure used in the calculations of requirements. These data cells are called "time buckets". A weekly time bucket which contains all of the relevant planning data for a whole week is considered to be necessary for immediate and medium period planning by MRP system, where monthly buckets are considered too rough.

A bucketless MRP system specifies the exact release and due dates for each requirement, using scheduled receipt (i.e. which represents a commitment, whereas the planned order is only a plan) and planned orders (Vollmann et al., 1992).

h) Average number of weeks in MPS: Plossl states "time periods of MPS must be identical to those of MRP; typically they are one-week periods" (1995, p.49).

Anderson et al. (1984); Laforge and Sturr (1986) and Sum & Yang (1993), report in their studies that typical MRP uses operate a regenerative rather than a net change update method, employing cycle counting, higher percentage of pegging, updating MPS on a weekly basis, employing allocation of inventory, an automatic lot sizing unused, planning in weekly time bucket and the MPS planning horizon averaged ranged from 20 to 40 weeks.

Furthermore, it is believed that the selection of features can help to "fine tune" an MRP system, resulting in achieving the highest benefits. However White et al. (1982) found that there are no a significant discriminatory powers regarding the relationship between system features and MRP implementation, namely success or failure of the implementation effort does not appear to rely on any particular feature of MRP system. Schroeder et al. (1981) found in their study that the only one of the technical characteristics of MRP system that had a significant effect on performance was time bucket size. They added that weekly time buckets are the best for obtaining high levels of performance. This seems to be because weekly time buckets provide about the right level of detail.

2.8.5 Human factors

As pointed out by several writers such as White et al. (1982); Wight (1983) and Callarman and Heyl (1986), that the problems with MRP implementation relate to people, and are not technical in nature. Vollmann et al. (1992) argue that the implementation of any manufacturing planning and control system such as MRP requires a large number of professionals. They added that MPC system tasks involve the largest number of indirect persons that may be working in the entire company. Goh (1984) considers that the critical elements in the implementation of MRP system are sorted into three categories (i.e. the people, data and computer). Related to the importance of people for implementing MRP system Turnipseed et al. (1992) conducted a survey regarding an implementation analysis of MRP systems: focusing on the human variable on 72 companies in the US, they found that the previous experience with CAPM systems, level of formal training, degree of user involvement, degree of user support and degree of utilising MRP outputs have been considered as the critical human factors affecting the implementation of MRP system by manufacturing companies.

2.8.5.1 The previous experience with CAPM systems

Burns et al. (1991) suggest that one of the problems with MRP implementation is that operations/production managers involved in the implementation have not had previous experience in the implementation of complex information systems. In contrast, despite MRP systems requiring advanced knowledge of computers and information systems, Turnipseed et al. (1992) found in their study that there is a low relationship between the outcome variables of MRP implementation such as increased job satisfaction, improved job performance, improved the quality of information etc. and prior experience with technically advanced information systems.

2.8.5.2 Education and training

According to Hall and Vollmann (1978); Maertz (1979); Cox and Clark (1984); Dilworth (1993); Lunn (1994); Plossl (1995) and Browne et al. (1996), the people in MRP companies should understand what MRP is all about for successful implementation and learn to use MRP as an effective tool for it to be successful. Safizadeh and Raafat (1986) and Cruz (1997) add that education and formal training can be regarded as one of the fundamental issues that determines the successful implementation of an MRP system. Moreover, although the technology is generally adequate with regard to computer hardware and software, and associated machinery, the prime problem is that people who are presumed to operate the system such as MRP may be ill prepared (Shaw and Regentz, 1980).

As stated by Safizadeh and Raafat "Education refers to the process of providing the management and employees with a rationale for change to the MRP system and making them familiar with the technical and nontechnical aspects of the system" (1986, p.116). The educational effort should be conducted in a cross-functional/facility environment in order to build up skills necessary for effective implementation such as communications, influence, conflict resolution and effective meetings (Iemmolo, 1994).

Moreover, it is thought that education will increase management's understanding of MRP I/MRP II concepts and then it will help for understanding the need for the MRP system such as developing formal policies and procedures and distributing responsibilities (Duchessi et al., 1989). The education effort may be conducted outside the company at other companies working towards the same objective. This can be considered as a good opportunity to hearing what problems other companies are having and to show management what are the common problems (Correll, 1994).

While training deals with the actual tasks and procedures which are necessary to ensure operating personnel to effectively perform their duties and use the new technology. Each person in the organisation must have to attend at MRP training sessions (Maertz, 1979; Sheldon, 1991). MRP training can be divided into three types of training as follows: a) generic training which describes the MRP process and provides basic understanding of the various modules that comprise an MRP system, b) software orientation which describes how the unmodified software will function when installed, c) application training which describes how the MRP system will function in the company environment (Millard, 1989).

With education and training confidence among MRP users will be increased and should enhance their performance on the job and then the greater efficiency can be obtained.

Duchessi et al. (1989) found that nearly two thirds of both successful and less successful companies had senior management attending an MRP overview session and project team members educated in MRP, therefore education has become recognised as a critical implementation step (Sheldon, 1994).

Anderson and Schroeder (1984) found in their study regarding getting results from MRP systems by the American companies that education of personnel represent the major problem that face companies in implementing MRP system.

Turnipseed et al. (1992) found that 73% of respondents are college graduates. They also found a strong positive correlation between the higher the level of formal education and training and the ability of MRP users to perform their job.

2.8.5.3 User involvement

One of the main prerequisites for the successful implementation of an MRP system is that all people and all managers are involved in its implementation (Turbide, 1990; Dugger, 1996). According to Hoyt (1977) the necessity of user involvement is to protect the users from "data processing mentality", because data processing people often think they must be calling the shots. They cannot understand what users need because they think too much in terms of efficiencies through computer use. He adds that there are several ways in order to get user involvement such as meeting with users in order to inform them what the MRP project is and in order to get an idea about what they want the project to be, training people in order to be familiar with the system, and finally documenting what goes into the system. Moreover, Dilworth (1993) argues that participation of users of the system in its development will make them more familiarised with it, and then more involved.

Turnipseed et al. (1992) found that 50% of MRP users were involved in implementing MRP system whether by leading the implementation or being active with the implementation on at least a weekly basis. They demonstrated that user involvement is positively correlated with some positive outcomes obtained from MRP implementation such as simplifying the performance on the job. Dugger (1996) reported that the involvement of business managers with MRP users within the MRP implementation context such as attending their weekly project meeting at the SEQUUS Pharmaceutical Company led to accelerating the development and helped users to take their role more seriously. In this sense, Leng (1987) suggests that the successful implementation of MRP system not only requires a great deal of time and effort on the part of many people throughout the company, but also virtually all departments in the company must be involved in MRP implementation.

2.8.5.4 User support

As a whole, the level of user support has often been identified as one of major implementation prerequisites (Callarman and Heyl, 1986; Dilworth, 1993). Desmond and Wilson (1989) in their study regarding the implementation of CAPM system such as MRP system on four companies in the UK highlight the importance of user support as a major factor affecting the implementation of MRP systems, specifically from middle management. Turnipseed et al. (1992) found that 89% of MRP users in the US were at least supportive implementing MRP systems. They found that there is a strong relationship between level of user support provided for MRP implementation and most of outcome variables of such implementation, for instance improved ability of the user to perform his/her job.

Moreover, Sum et al. (1995) reported that at the outset of the implementation of the formal MRP system there will be data inaccuracy, mishandling, increasing resistance etc.. This makes the people lose confidence in the formal system and rely on informal systems to accomplish their work. However, with process of time they will start to realise the importance of the formal system. In turn they will be oriented to rely on it to accomplish their work which may lead to increased operational efficiency. And also, they found that higher people support is needed for higher coordination among subsystems and departments within the MRP context.

2.8.5.5 Degree of utilising MRP outputs

Turnipseed et al. (1992) reported that forty four percent of respondents indicated that they are using the MRP system daily to perform their job. They demonstrated that the outputs obtained from MRP implementation such as increased information, improved information quality etc. led to an increase of the degree of utilising MRP system.

2.9 Summary

This chapter of the study has shown that the new manufacturing environment imposes some challenges on manufacturing companies, for instance to offer more advanced and quality products, fulfilment of customer needs and faster delivery times.

The effective development of new manufacturing planning and control systems has enabled manufacturing companies to meet these dramatic changes. Consequently, MRP, JIT and OPT systems have been developed as new systems for manufacturing planning & control so as to ensure that productivity is maintained, stocks are minimised and resources are optimised, in turn achieving manufacturing efficiency and effectiveness.

Also, it was shown that MRP systems still number one concerning the widespread implementation among the latest MPCs, namely MRP, JIT and OPT. MRP in and of itself does not achieve the expected commercial results within manufacturing companies unless it is carefully applied. Successful applications on these where such systems are married with a range of others activities, factors and strategies. Successively, after identifying and determining the role and the significance and the developments of MRP systems, comes their role in successful implementation. We discussed the activities and factors which are related to the implementation of MRP systems by manufacturing companies.

In sum, a review of the literature and previous empirical studies reveals that there are several gaps that need to be empirically investigated. These are:

(1) Much has been written about how to implement MRP I/MRP II based upon case studies or personnel experience. Very little is written about understanding the state of MRP practices based on an empirical survey analysis of multiple companies.

(2) No previous empirical study has tried to investigate MRP implementation in less developed countries, such as Egypt.

(3) There is only a handful of studies dealing with the benefits obtained from MRP implementation by manufacturing companies (Schroeder et al., 1981; White et al., 1984; Anderson and Schroeder, 1984; Sum and Yang, 1993).

(4) Only two studies have attempted to investigate the stage of MRP implementation by MRP users (Cooper and Zmud, 1989;1990).

(5) Only one study has been conducted to explore and examine the explanatory variables of MRP system effectiveness, the so called MRP benefit-determinant relationships (Sum et al., 1995).

(6) There is a scarcity of studies relating to the impact of the human aspects on MRP implementation.

(7) There are no empirical studies that have attempted to explore and examine the relationship between the uncertainty factors and MRP implementation.

(8) There is a lack of studies conducted to analyse the cost spent on MRP implementation by manufacturing companies.

The current research aims to fill empirically the previous mentioned gaps. Therefore, a conceptual model has been established to provide a greater understanding of the subject matter. This serves to outline the major inputs which have been employed to accomplish the objectives of the study. Figure 2.11 shows a conceptual model for conducting this study.

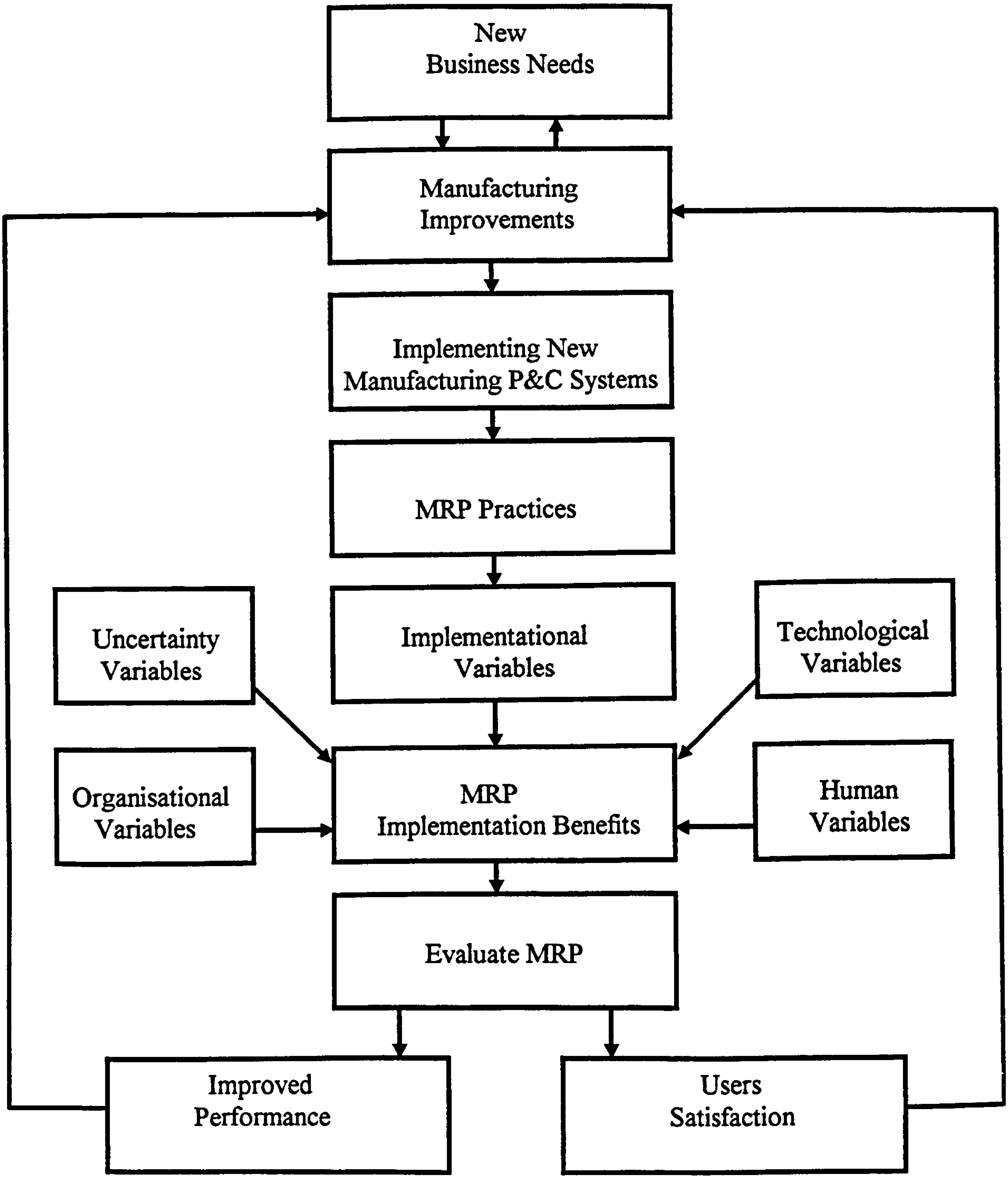


Figure 2.11 Conceptual model of MRP implementation (Constructed by the researcher).

More specifically, a suggested model framework of the explanatory variables of MRP benefits has been established to outline the effectiveness of MRP implementation measured by the expected potential and the actual benefits obtained from MRP implementation and to state the explanatory variables of such effectiveness. This is shown in Figure 2. 12 below:

Figure 2. 12 A suggested model framework of the explanatory variables of MRP implementation benefits

Determinant Variables	MRP Implementation Benefits
Uncertainty Determinants	***Tangible Benefits***
Product characteristics diversity	Inventory turnover
Amount of aggregate product demand	Delivery lead time (days)
Machine downtime	Percent of time meeting delivery promises (%)
The standard of raw material	Percent of orders requiring "splits" because of unavailable material (%)
Behaviour of people within the factory	Number of expediters (number of People)
Reliability of plant within the factory walls	***Subjective Benefits***
Capacity constraints	Improved competitive position
Organisational Determinants	Reduced inventory costs
Company age	Increased throughput
Company size	Improved product quality
Type of products	Improved productivity
Type of Manufacturing	Better ability to meet volume/ product change
Layout	Better production scheduling
Company complexity	Reduced safety stocks
Organisational arrangements	Better cost estimation
Organisational willingness	Improved co-ordination with marketing and finance
Implementational Determinants	Improved your ability to perform in your job
Years in implementation	Reduced informal systems for materials management/ inventory/ production control
Implementation strategy	Increased BOM/inventory/MPS accuracy
Degree of data accuracy	Increased information on which to base decisions since MRP has been implemented
Initiator of MRP effort	
Software/hardware vendors support	
Implementation problems	
Technological Determinants	
Degree of integration among MRP modules	
Source of system	
System cost	
Additional investment over next 3 years	
User class (stage of MRP implementation)	
MRP system features	
Human Determinants	
The previous experience with CAPM Systems	
Education and formal training	
User involvement	
User support	
Degree of utilising the outputs of MRP	

To investigate conceptual model framework of MRP implementation and a suggested model framework of the explanatory variables of MRP effectiveness, the current study seeks to investigate the state of practice of MRP systems in Egypt as a less developed country (Chapter 5), to assess the effectiveness of MRP practices measured by the benefits obtained from MRP implementation, and to explore and examine the explanatory variables of MRP system effectiveness (Chapters 6&7). To do that, firstly an overview of the manufacturing sector of Egypt will be presented in order to acquaint the reader about the main features of the manufacturing sector under investigation (Chapter 3), then secondly the methodology for achieving the objectives of the current study is developed as shown in (Chapter 4).

CHAPTER THREE

The Manufacturing Sector of Egypt

3.1 Introduction

The overall objective of the present chapter is to acquaint the reader with the main features of the Egyptian manufacturing industry sector. To achieve this end, this chapter is divided into the following: The first section provides an overview of the manufacturing sector in Egypt starting with its main subsectors, its objectives, its significance, trade in manufacturers (imports and exports) and the main problems facing the manufacturing sector in Egypt. The second section deals with computerisation in the Egyptian industrial sector. The final section states the summary and conclusions of this chapter.

3.2 An overview of the manufacturing sector in Egypt

As pointed out by several writers such as Per-lind (1991) and UNIDO (1994), the manufacturing sector in Egypt is one of the most important sectors in accomplishing Egypt's development goals which are: raising production and productivity, and overall living standards, and establishing its market leadership in the face of global competition and protectionism. It has expanded very quickly since the mid-1980s. Improving manufacturing labour productivity has increased along with overall manufacturing efficiency and effectiveness.

In general terms, the Egyptian industrial sector is characterised by a) labour intensive industries like textiles, food and assembling, b) substantial geographical dispersion-for instance, there is manufacturing industry in Cairo, Alexandria, Helwan, Tenth of Ramadhan City, and Sixth of October City, c) a low proportion of private sector industry-despite the era of transformation from public to private sector, there is an only 40 out of 314 companies exposed to be privatised (Album, 1997), moreover of the 40 companies which have been privatised a majority of their equities are still held by the Egyptian government in order to give the investors more confidence in the protection of their rights. This means that one of the main characteristics of the Egyptian industrial sector is a large share of government-owned enterprises

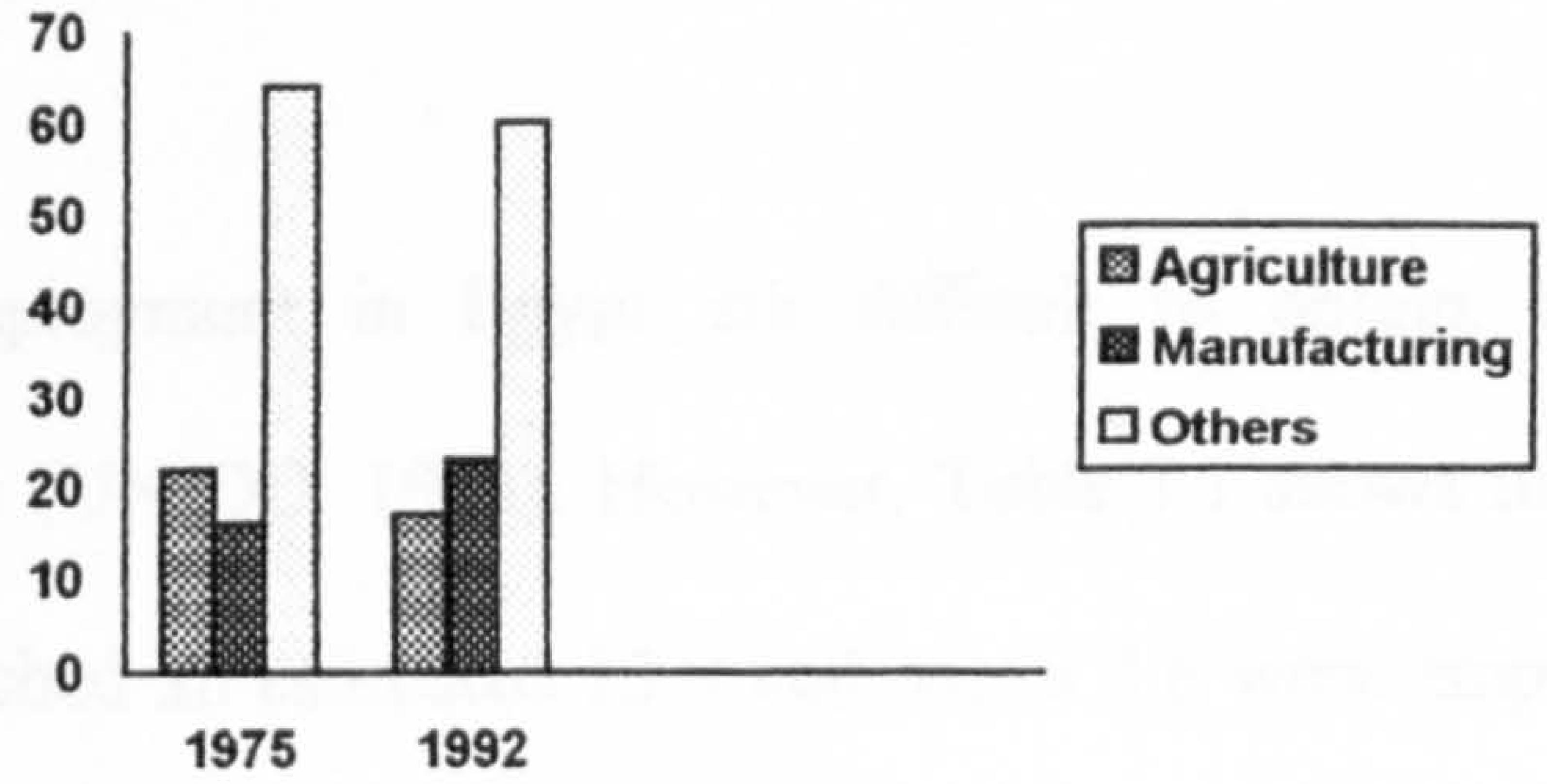
3.2.1 The main subsectors within the Egyptian manufacturing sector

The manufacturing sector in Egypt is broken down into two main subsectors according to ownership. The public sector consists of approximately 200 state-owned companies and the private sector consists of approximately 15,000 private-owned establishments.

According to UNIDO (1994) and DTI (1996), the Egyptian industrial sector consists of a limited range of industries. These are: Textiles, Mining and petroleum industries, Drink and tobacco, Engineering, Garments, Chemicals, Leather, Wood, Food industries, Paper, Printing, and Plastics industries.

The manufacturing sector of Egypt plays an important role in the Egyptian economy. Figure 3.1 shows that it has expanded at very rapid rates since the mid-1970s, with the share of MVA in total GDP estimated to have risen from about 16 per cent in 1975 to almost 23 per cent by 1992.

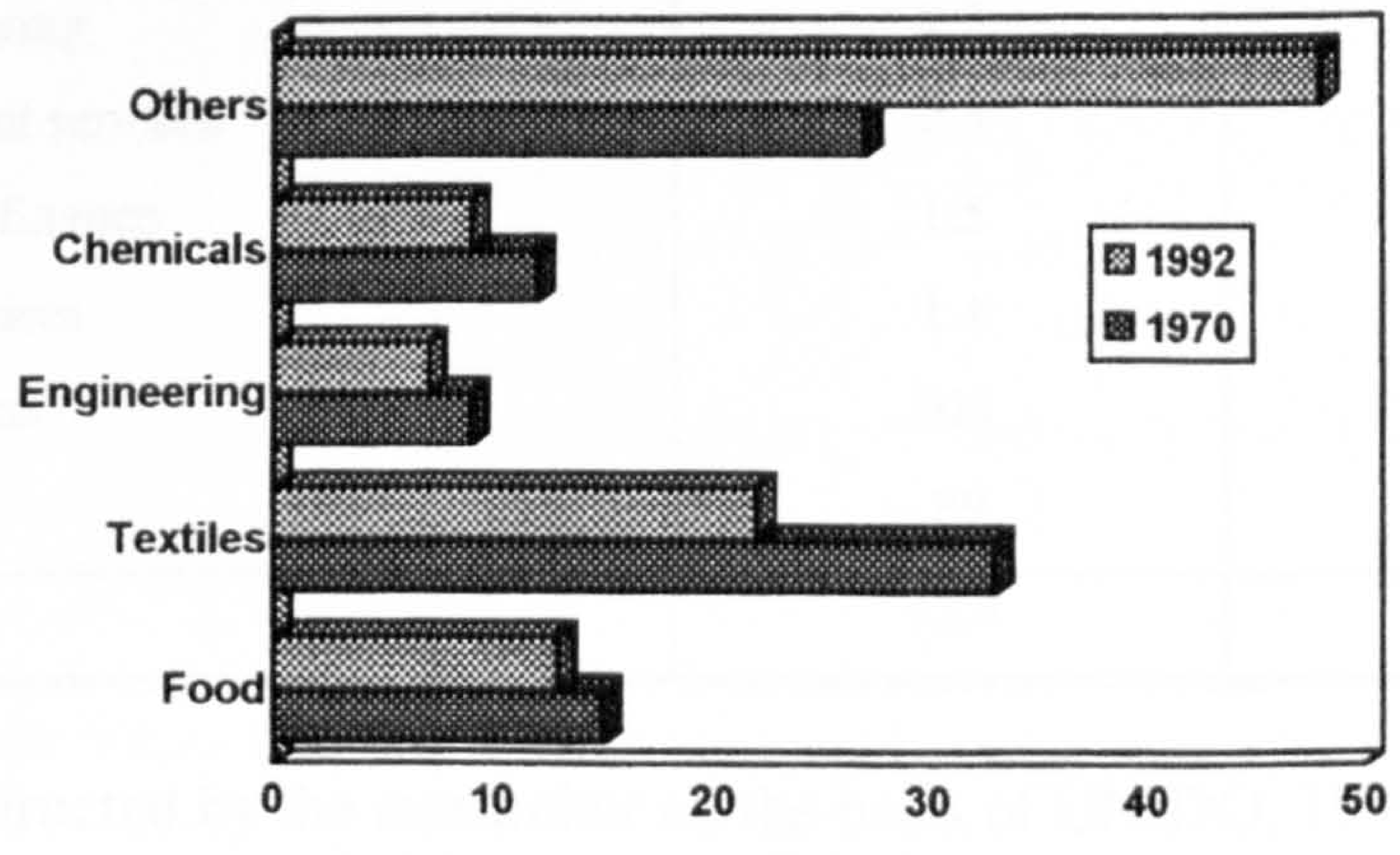
Figure 3. 1 Structure of GDP by sector of origin, 1975 and 1992.



Source: Constructed by the researcher on the basis of UNIDO, 1994.

However, four subsectors, i.e. foods, engineering, textile, and chemicals, form the main industrial structure in Egypt in terms of Manufacturing Value Added (MVA) and industrial employment. Figure 3.2 shows the Manufacturing Value Added of the Egyptian industrial sector, 1970 and 1992.

Figure 3. 2 Structure of manufacturing value added (MVA), 1970 and 1992.



Source: Al Ahram International, March 1996, p.14.

Despite the Manufacturing Value Added (MVA's) for the four subsectors was declined from 1970 to 1990, they still form more than 50% of the MVA of the Egyptian industrial sector.

Data on employment in Egypt are difficult to obtain, particularly for the manufacturing sector (UNIDO, 1994). However, Table 3.1 shows that total employment in the fiscal year reached an estimated 13.9 million, of 4.6 were employed in agriculture, 2.9 million in industry, mining and petroleum products sector, 2.5 million in government services and social insurance, 1.5 million in trade, finance & insurance and 911,000 in construction. The remainder are employed in tourism, hotels and restaurants and electricity.

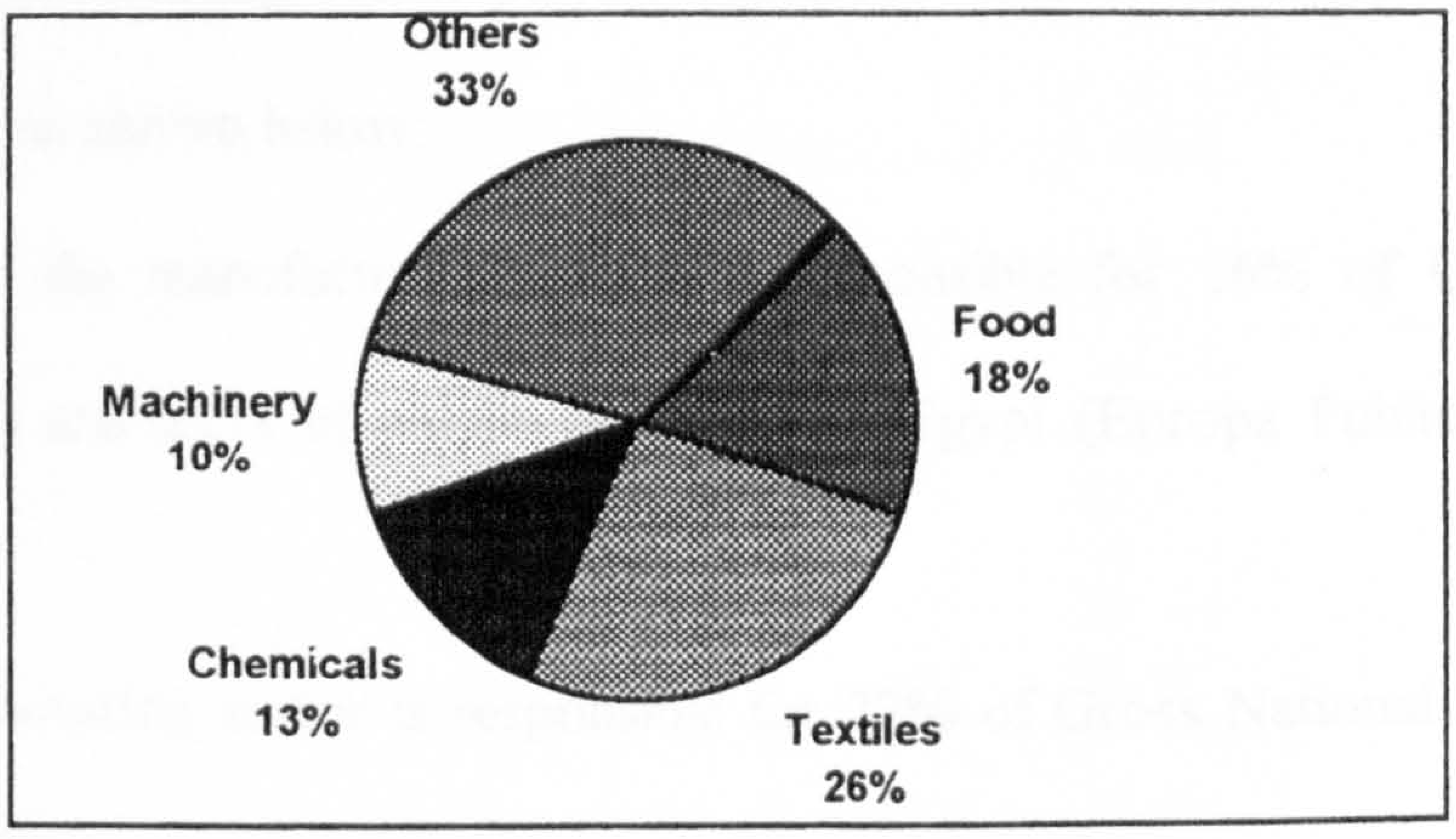
Table 3. 1 Distribution of total employment among the Egyptian economic sectors in 1992 (million).

Sectors	N	%
Agriculture	4.6	33.1
Manufacturing	2.9	21.0
Government services	2.5	17.7
Trade and finance	1.5	10.5
Social services	1.4	10.1
Construction	.911	7.0
Other	.89	.6
Total	13.9	100%

Source: Constructed by the researcher on the basis of UNIDO, 1994 and Europa Publications Limited, 1996.

On the other hand as reported by UNIDO (1994) textile production, food processing, machinery, chemical industries remain the most important sources of manufacturing employment. Figure 3.3 states that the share of total manufacturing employment held by the foods, machinery, textile, and chemicals industries is 67% of total manufacturing employment in the Egyptian industrial sector.

Figure 3. 3 Structure of manufacturing employment, 1990.



Source: Constructed by the researcher on the basis of UNIDO, 1994.

3.2.2 Manufacturing sector objectives

Manufacturing industry in Egypt basically aims to achieve the following:

(1) Exploiting the available economic resources such as: raw materials, and human resources.

(2) Improving the technical methods of existing industries through modern techniques and automation for increasing quality.

(3) Diversifying the material economic base in order to create new sources of income, which at the same time avoiding dependency on any one sector as the main income resource.

(4) Developing other sectors through using their outputs as inputs to other industries.

(5) Satisfying the needs of domestic markets through providing goods instead of importing them from outside, and potentially exporting the surplus.

(6) Creating productive employment.

3.2.3 The significance of the Egyptian manufacturing sector

The manufacturing sector plays a significant role in the Egyptian economy for several reasons as shown below:

(1) In the 90s the manufacturing sector is responsible for 16% of Gross Domestic Product (GDP) and 21% of employed labour in Egypt (Europa Publications Limited, 1996).

(2) The manufacturing sector is responsible for 22% of Gross National Product (GNP) (Al- Gebaly, 1996).

(3) It was the fastest growing sector in the last five-year Plan from 1987/1988 to 1991/1992, with an annual growth rate of 8.4% (Fiani and Partners, 1992).

(4) The share of value added in the gross output of manufacturing sector in Egypt has risen significantly since the mid-1970s, from 26.6% in 1975 to 31.4% by 1990 (UNIDO, 1994).

(5) The total investment expenditure in the industry and mining sector is 22.8% of the total investment expenditure in the Egyptian economic sectors in last two five-year plans, covering the period from 1982/1983 to 1991/1992 (Ibid.).

(6) Data for the manufacturing sector in Egypt are more readily available than in other sectors such as agriculture, services etc.

3.2.4 Trade in manufacturers

(1) Imports: Although Egypt has increased its industrial production considerably since the 1920s, the country is still a major importer of capital and manufactured goods, particularly from Europe. Table 3.2 states the main imports by the Egyptian economic sectors in 1994.

Table 3.2 The main imports (E.L*'000).

Commodity	1994
Wheat	2,501,168
Wheat flour	235,381
Maize	892,463
Chilled/frozen meat	534,744
Dairy products	509,404
Refined sugar	52,305
Trucks	259,796
Automobiles	746,461
Vehicle & tractor parts	762,050
Iron rods and bars	90.781
Excavating machinery	322,704
Chemicals	1,107,298
Cement	51,744

* $1 = L.E. 3.39.

Source: Financial Times, May 1996.

Table 3.2 indicates that the total imports by industrial subsectors such as chemicals, engineering and assembling, excavating machinery etc. represents approximately 41.4% of the total imports by the Egyptian economic sectors.

(2) Exports: Table 3.3 indicates that chemical products and textiles products are the most important categories of the main exports of the Egyptian economic sectors in 1994.

Table 3. 3 The main exports (E.L*'000)

Commodity	1994
Crude oil	2,684,977
Raw cotton	791,081
Cotton yarn	1,279,541
Cotton fabrics	409,030
Clothing	780,342
Non-crude, shale oils	742,075
Unwrought aluminium	94,433
Refined sugar cane	295
Oranges	27,841
Rice	267,875
Potatoes	98,205
Aluminium rods & sections	405,438

* $1 = L.E. 3.39.

Source: Ibid.

From these figures one can see the important role played by imports and exports by of Egyptian industrial sector in the Egyptian economy. For this reason the Egyptian government has been encouraging manufacturing companies to adopt new technologies such as MRP systems, in order to raise production and productivity, in turn establishing their market leadership and protectionism. As a result, the Egyptian government continues to make current incentives available for manufacturing companies such as tax relief, financial assistance, grants, subsidies, free training and consultancy services.

Moreover, there has been increased the investment in this sector. Table 3.4 shows that public and private investment in industry grew from LE 13.4 billion during the first Five Year Plan ending in June 1987 to LE 25.7 billion during the second Five Year Plan ending in June 1992. This represents 22.9 per cent of total investment. For the current plan period, 1992/1993 to 1996/1997, the government is expecting total investment in industry to reach LE 28 billion. This would represent about 18.2 per cent of the total overall investment - LE 154 billion _ targeted for the five - year period.

Table 3. 4 Public and private sector investment expenditure, 1982/1983-1991/1992-1996/1997 (Million L.E*).

Economic sectors	1982/1983 to 1986/1987	1987/1988 to 1991/1992	1992/1993 to 19996/1997
Total investments	56,322.3	114,924.4	154,000
Industry	13,375.1	25,741.5	28,000
(% of total)	23.7%	22.4%	22.9%

* $1 = L.E. 3.39.

Source: Constructed by the researcher on the basis of UNIDO, 1994.

3.2.5 The main production problems in the Egyptian manufacturing sector

As a whole, the industrial sector in Egypt, as in many developing countries, is confronted with a variety of obstacles and problems of an economic, organisational and technical nature (Per-lind, 1991). He also reported, that the main reasons for production stops in one of the biggest public companies in Egypt (i.e. NASCO) are: machine breakdown, tools missing and defective, electricity failures, operator absent, and material missing. Furthermore, El Gebaly (1996) pointed out that the Egyptian manufacturing companies face increasing regional and international competition, specifically from their neighbours such as Israel, Turkey, and Iran.

In summary, Helmy (1996) reported in his study about how the Egyptian manufacturing industry can be promoted to the world level, that Egyptian manufacturing companies are suffering from the following obstacles:

(1) In general, the data and information about production are scarce, and if available they are incomplete or discrepant i.e. there is a discrepancy for the same information if it is drawn from more than one source.

(2) Effective co-ordination among departments is not likely to occur, because there is discrepancy in complaints raised by marketing, finance, purchasing, and production departments.

(3) Lack of automation expertise, and also training and education can be identified as major problems facing manufacturing companies in the Egyptian industrial sector.

(4) Increases in all types of inventory such as raw materials, parts, components, finished goods and spares.

(5) Decreasing product quality level compared to its peers in the international markets and increasing disorder in production scheduling and loading.

(6) Despite the continuous expansion of the industrial sector in Egypt since the 1920s, there is no substantial impact on the import substitution or exports of manufactured goods as in other sample countries (Per-lind, 1991).

Since MRP systems can help manufacturing companies to overcome the problems mentioned above, or the majority of them, many manufacturing companies in Egypt have implemented, are implementing, or are considering the implementation of MRP systems.

3.3 Computerisation in the Egyptian manufacturing sector

Per-lind (1991) pointed out that attempts are continually made by the Egyptian government to improve industrial efficiency - they are encouraging the use of computers for specific support functions such as materials requirements planning.

The first computers were introduced into Egypt in 1962, and after approximately two decades the number of computers had reached 120 in the government public sector.

The first computers to be installed at a university was at the University of Alexandria in 1964, followed by Cairo University and Ain Shams University in 1968-9.

With the beginning of the open door policy in 1974-5, a number of computer vendors were attracted by the opening Egyptian market. They are approximately thirty vendors, through ICL, IBM and NCR together represent nearly 60 per cent of all installed computers. According to Per-lind about 10 percent of all installed computers can be characterised as well utilised, efficient and achieving their objectives, whereas 90 per cent are regarded as (inefficient) in one way or another. Nonetheless, the growing number of installations is obvious. Public manufacturing companies like textiles, automobiles, iron and steel and chemical have implemented computer systems but the major applications areas have been: payroll, accounting, costing and inventory accounting, on-line maintenance management, process control, and materials management.

Per-lind gave in his book a very short description about the Material Requirements Planning system that has been implemented by El Nasr Company, the biggest company producing vehicles in the Egyptian manufacturing sector.

The MRP system at NASCO adheres to a formal technique that is common to all computer-based MRP. The system is regarded as necessary by the production planning management for all material acquisition activities, for external as well as for internal supply. Its outputs form the basis for initiating purchase and manufacturing orders.

3.4 Summary and Conclusions

The main purpose of this chapter was to review the current characteristics of the Egyptian industrial sector and its associated problems. Examining these issues had led to developing the following conclusions:

(1) Despite an era of transformation from public to private sector, a large public sector still dominates control structures over industry is still a major characteristic in Egypt.

(2) In spite of the Government's radical economic reform programme for the Egyptian industrial sector, it still suffering from several problems such as: decreasing market share and too much inventory confirming that new production technologies are needed. MRP systems are one such example.

(3) The Egyptian industrial sector in particular has shown the growing appreciation of the acquisition of new production technology (e.g., MRP systems) as a suitable path for improving manufacturing efficiency and effectiveness.

For achieving the objectives of this study a proper design of the methodology is developed as shown in next chapter (Chapter 4).

CHAPTER FOUR

Research Methodology

4.1 Introduction

The main purpose of the current study is to investigate the state of practice of MRP systems in Egyptian manufacturing companies, to assess their effectiveness (i.e. the tangible & subjective benefits obtained from MRP implementation based upon the expectations and perceptions of MRP users), and to explore and examine the relationships between a set of uncertainty, organisational, implementational, technological and human determinant variables and the tangible and subjective benefits attained by Egyptian users. Without proper design of methodology, a study cannot achieve its objectives. Therefore, the overall aim of this chapter is to describe the procedures, steps, and methods used in the study in order to achieve the research objectives.

To do this the chapter is divided into two main parts. The first part sheds some light on the major types of research design and research methods that are available to social scientists (this is briefly covered in sections 4.2.1 & 4.2.2). The second part presents the design or strategy adopted for this study and which has passed through eight successive stages (from section 4.3.1 to section 4.3.8). These are: the first section presents research questions and objectives, the second section describes how the study variables were determined, the third section deals with formulation of the study hypotheses, the fourth section identifies the population for this study, the fifth section shows development of the questionnaire, the sixth section deals with identification of the appropriate data collection method, the seventh section displays response rate, the eighth section presents data analysis methods.

4.2 Types of research design and research methods

4.2.1 Types of research design

According to Emory (1985) several definitions of "research design" have been developed, but no one definition tells the full range of substantial aspects. Kerlinger (1986, p:279) defines research design as "the plan which is overall scheme or program of research. It includes an outline of what the investigator will do from writing the hypotheses and their operational implications to the final analysis of the data". And also, research design can be regarded as the overall strategy that includes total planning for the investigation (Nachmias and Nachmias, 1992), or the overall structure of the plans used for collecting data. Kerlinger (1973) states that "strategy implies how the research objectives will be reached and how the problems encountered in the research will be tackled" as cited in (Emory, 1985, p. 59).

Oppenheim (1992) offered a more general definition which emphasises that research design refers to the basic plan or strategy of research and which enables the investigator to draw general conclusions from it or which enables him/her to obtain answers to research questions (Kerlinger, 1986).

Accordingly, these definitions can give the essentials of a good research design. "First, the design is a plan that specifies the sources and types of information relevant to the research question. Second, it is a strategy or blueprint specifying the approaches to be used for gathering and analysing data" (Emory, 1985, p. 59).

According to Kerlinger (1986); Nachmias & Nachmias (1992) and Brownell (1995), research design can be classified into three major types as follows:

4.2.1.1 Experimental design

The experimental research design occurs "when the subjects (people or social systems) and conditions (events or situations) to be studied are manipulated by the investigator. The key to experimental design is that the investigator assigns subjects to conditions rather than observing them in naturally occurring situations" (Spector, 1993, p. 1-2). This type of research design is best illustrated by the laboratory experiment. Therefore, it is mainly used by researchers in the biological and physical sciences (Nachmias and Nachmias, 1992).

The major advantage of the experimental design is that it allows us to determine causality (Spector, 1993; Whitley, 1996). However, this type of research design has its own drawbacks since it is often difficult to control all external factors and therefore difficult to establishing causality (Spector, 1993), as well as it can only be used to study independent variables that can be manipulated (Whitley, 1996).

4.2.1.2 Case study design

This type of research design can be defined as a classic way of obtaining detailed information about a single individual (Elmes et al., 1992), or it is intended to provide in-depth information on the details of a single instance of a phenomena for either descriptive or hypothesis-testing purposes (Whitley, 1996; Nation, 1997). However, the researchers often tend to think of the case as a tool for description rather than hypotheses testing (Whitley, 1996).

The main advantages of the case study design are summarised as follows (Brownell, 1995; Whitley, 1996; Nation, 1997): It allows the researcher to investigate rarely occurring phenomena, compared to the experimental strategy which is based on the use of the large numbers of cases. It can to be used to study phenomenon that occurs infrequently. It allows the researcher to gain a new point of view on a situation and also, it is useful for developing materials for teaching purposes. However, three significant disadvantages of the case study approach are: the impossibility of drawing conclusions about causality, its limited generalizability, and its vulnerability to researcher bias (Al-Shauaibi, 1991; Whitley, 1996; Nation, 1997).

4.2.1.3 Survey design

As stated by Whitley (1996, p. 417) the survey design can be defined as: "the process of collecting data by asking questions and recording people's answers". He adds that there are two purposes for using survey design: First, is to estimate the characteristics of a population such as to determine the percentage of people who perform certain behaviours (e.g., smoking cigarettes) or the demographic characteristics of the population (e.g., age and sex), second is to test hypotheses.

The major advantages of the survey design (Stone, 1978; Kerlinger, 1986; Brownell, 1995) are: results allow for generalisation because the sample is representative of the population, a great deal of information can be obtained, its information can be accurate because of large sample sizes and low sampling errors and also it is a powerful tool in analytic studies undertaken to test specific hypotheses. However, the survey design also has its own disadvantages such as survey information does not penetrate very deeply below the surface, it requires time and money, and also requires a good deal of research knowledge.

4.2.2 Research methods

The previous subsection has covered the three types of research design. In this subsection, research methods will be introduced as techniques for collecting primary data. There are several choices concerning the means of collecting primary data. Normally these include questionnaires, interviews, observations, and archival records.

4.2.2.1 Questionnaire method

Questionnaires are simply lists of questions that research respondents are asked to answer. It can be either self- administrated in which case respondents read printed questions and answer in writing, or interviewer administrated, in which case a researcher asks the questions and records the respondent's answers (Whitley, 1996).

The principal advantages of the questionnaire are summarised by Al-Shauaibi (1991); Oppenheim (1992) and Fife-Schaw (1995) as follows: it appears to be simple, it is versatile, its cost is low for data gathering, it provides a good enough quality of the required data for testing hypotheses or making decisions, it is a well understood technique, it provides a level of anonymity to the respondents, and also it can cover many more people than an interview method which allows the researcher who is limited in terms of time and effort to meet a little number of interviewees or respondents.

However, it has its disadvantages such as it requires a great experience concerning how to design a good questionnaire because the perfect questionnaire is impossible, the response rate is often poor, it often needs follow-up of non-respondents, and this is problematic where anonymity of the respondents is guaranteed (Brownell, 1995; Fife-Schaw, 1995).

4.2.2.2 Interview method

The interview is another technique for collecting data. According to Whitley (1996) in an interview the researcher asks questions of a research respondent, who then responds. Interviews can take place in person, in a face to face meeting between the interviewer and interviewee or over the telephone, and respondents can participate either in groups or individually. Breakwell (1995) adds that an interview can be designed as unstructured, semi-structured, or structured based on the extent to which the questions and the order they are asked are planned in advance of data collection.

Using interviews, many advantages could be gained such as motivating the respondent to supply accurate and complete information immediately, guiding the respondent in his/her interpretation of the questions, giving a greater flexibility in questioning the respondent, allowing a greater control over the interview situation because: a) the respondent deals with questions in a certain sequence, b) the respondent will not consult others in giving his/her answers, and evaluating the variability of information by observing the respondent's non-verbal manifestations of his/her attitude toward supplying the information (Churchill, 1991; Ghauri, 1995).

However, the interview method has its own drawbacks in that it is costly, the risk of interviewer bias is expected (Brownell, 1995), and the waste of time for the interviewer- for instance the interviewer may spend some time for preparing the interview in terms of booking an appointment with the interviewee, and also he/she may spend some time to make the interviewee in a relaxed and friendly manner before conducting the interview (Whitley, 1996).

4.2.2.3 Observation method

Observation means that the investigator keeps watching a case very carefully (people or subjects) as it occurs in natural settings in response to natural events to record what can be observed (Al-Shauaibi, 1991).

There are several advantages to be gained in using this method for data collection, it allows the researcher to oversee natural behaviour in its natural context (Whitley (1996), observations can be regarded as a good source of ideas for further research (Elmes et al., 1992), furthermore Nation (1997) states it allows the researcher to count and record behaviours that may occur infrequently over a long time span.

In contrast, the disadvantages of observation method include: observer bias, observers often need considerable training otherwise he/she can make incorrect inferences from observation, people under the observation may change their behaviour when they are aware that they are part of research to show themselves in a favourable light, and also it is costly because it requires the observer to be present all times (Stone, 1978; Kerlinger, 1986; Nachmias and Nachmias, 1992; Whitley, 1996).

4.2.2.4 Archival records method

The final method for collecting data is through archival records method. As pointed out by Whitley (1996) archives are records or documents that describe the characteristics of individuals, groups or organisations. There are three types of archives: First, statistical archives which store data in summary form such as public health records, second survey archives which include the people's responses to national surveys of public opinion, and finally written and electronic records which include the speeches and writings in the public domain which reflect attitudes, beliefs, and motivations.

The major advantages of this method are summarised by Al-Shauaibi (1991) and Nachmias & Nachmias (1992) as follows: the low costs and the accessibility to the data in most cases (e.g., national health records, demographic data such as age, sex, etc.). However it has its own drawbacks such as the problem of accessibility (e.g., the individuals might not want to release private documents such as diaries and letters), and the problem with the validity of information in archival records (Whitley, 1996).

4.3 Research design for the present study

In the previous section research designs and methods were covered along with their advantages and disadvantages for each type and method. In this section, the research design for the current study and the data collecting technique will be covered. However, it is worth stressing that a review of the literature of research methodology reveals that no single design is better than another (Al-Shauaibi, 1991; Nation, 1997).

However, there is some consensus among researchers in the research methodology domain that the appropriate design for any research must answer the research question and meet the research objectives (Hakim, 1987; Robson, 1993). On the other hand, the methodological options are restricted by the subject or the problem under investigation (Kerlinger, 1986; Easterby-Smith et al., 1991).

As a consequence, the survey design is considered to be the best method to meet the purpose of the current study because it provides the data required whether it was qualitative or quantitative or both (Kinnear, 1987). A decision has been made to use (the survey design (i.e. the empirical study) for the following considerations:

1. A Survey can investigate a large number of cases (companies in our research). It has been considered the appropriate method for the current study which attempts to investigate the state of practice of MRP implementation in the Egyptian industrial public sector which consists of 200 manufacturing companies.

2. A Survey can provide the required data for testing hypotheses or decision making. It has been considered the proper methodology for the current study which seeks to explore and examine the relationships between large numbers of independent variables (uncertainty, organisational, implementational, technological and human determinant variables) and dependent variables (MRP benefits measures).

3. Using the survey approach can help to compare the results of the current study with the handful of previous studies regarding MRP implementation which are based on survey design, such as Anderson et al. (1982); Duchessi et al. (1988;1989); Sum and Yang (1993); Sum et al. (1995) and Ang et al. (1995).

Despite the main constraint affecting the survey design being the extent to which respondents are willing and able to provide the required data, a carefully designed data collection instrument can help minimise this constrain. Therefore, a questionnaire is used to collect the data in this study. The main considerations in using the questionnaire were:

1. First of all a questionnaire has been regarded as the most common method for collecting data in surveys because it assures the confidentiality of data collected and the anonymity of participants (Al-Shauaibi, 1991).

2. The objectives of the current study, to test the hypothesised relationships will be accomplished by using several statistical techniques. Therefore the questionnaire is a proper tool for collecting the needed data.

3. It is suitable for an individual researcher who is limited in terms of time, effort, and money (Al-Shauaibi, 1991).

4. Building up the questionnaire from previous research (such as in our study) means that some items will have been well tested in other studies.

All in all, the research design of the current study (i.e. the survey design) and the data collection instrument (i.e. the questionnaire) are used to meet the objectives and to provide answers to the current study questions.

The design of the current research has passed through eight successive stages (from section 4.3.1 to section 4.3.8) as illustrated below.

4.3.1 Research questions and objectives

4.3.1.1 Research question

Taking into account the study background, it was decided that the first research question should be:

- *Have MRP systems been implemented as effectively in Egyptian manufacturing companies as in manufacturing companies in developed countries?,*

Once this research question had been selected, the thinking moved toward developing the main investigative questions which the researcher wished to answer. Three investigative questions represent the guide for gathering the data needed from individual Egyptian manufacturing companies and developing the research direction; these are:

- *Has your organisation implemented an MRP system?,*
- *What have been the benefits obtained from this MRP implementation, and*
- *What factors determined the extent to which MRP benefited your organisation, the so-called benefit-determinant relationships?.*

Once the investigative questions had been developed, the thinking moved on to determine the measurement questions. Those are what we actually asked MRP users and non MRP companies in Egyptian manufacturing companies. They appear on the questionnaire which contains thirty three questions seeking information that provide answers to the investigative questions.

4.3.1.2 Research objectives

The previous mentioned was the overall questions to be answered by the current study. To achieve that, there were three objectives representing the central concern of this study. These were:

- To investigate the state of practice of MRP in Egyptian manufacturing companies.
- To assess the effectiveness of MRP practices measured by the benefits obtained from MRP implementation based on the expectations and perceptions of MRP users in Egyptian manufacturing companies.
- To explore and measure the possible explanatory variables of MRP systems effectiveness in Egyptian manufacturing companies.

4.3.2 Determination of the research variables[1]

Taking into account the study purposes, and in order to place the present study in a proper perspective, it may be useful to outline a suggested model framework which states the overall variables underlying the structure, domain and the main approach of the present study and provides a foundation for the development of mathematical models for two kinds of MRP benefits measures (improved performances and user satisfaction). The content consists of both the identification of determinant variables affecting MRP implementation and also the benefits obtained from MRP implementation based on the expectations and perceptions of MRP users. The suggested model framework has been established based on an extensive review of the literature and previous empirical studies to select the uncertainty, organisational, implementational, technological, and human determinant variables and to identfy the tangible and subjective benefits obtained from MRP implementation (i.e. the effectiveness measures) from points of view of academics and practitioners. It will be operationalized and serves as inputs for the development of a research method (questionnaire). Figure 4.1 shows determinant variables of MRP implementation benefits:

[1] It is interesting to remind the reader that those variables i.e. independent variables (determinant variables) and dependent variables (MRP benefits) have been covered in details in Chapter two of the current study.

Figure 4. 1 A suggested model framework of determinant variables of MRP implementation benefits (study variables).

Determinant Variables	**MRP Implementation Benefits**
Uncertainty Determinants	***Tangible Benefits***
Product characteristics diversity	Inventory turnover
Amount of aggregate product demand	Delivery lead time (days)
Machine downtime	Percent of time meeting delivery promises (%)
The standard of raw material	Percent of orders requiring "splits" because of unavailable material (%)
Behaviour of people within the factory	Number of expediters (number of people)
Reliability of plant within the factory walls	***Subjective Benefits***
Capacity constraints	Improved competitive position
Organisational Determinants	Reduced inventory costs
Company age	Increased throughput
Company size	Improved product quality
Type of products	Improved productivity
Type of Manufacturing	Better ability to meet volume/ product change
Layout	Better production scheduling
Company complexity	Reduced safety stocks
Organisational arrangements	Better cost estimation
Organisational willingness	Improved co-ordination with marketing and finance
Implementational Determinants	Improved your ability to perform in your job
Years in implementation	Reduced informal systems for materials management/ inventory/ production control
Implementation strategy	Increased BOM/inventory/MPS accuracy
Degree of data accuracy	Increased information on which to base decisions since MRP has been implemented
Initiator of MRP effort	
Software/hardware vendors support	
Implementation problems	
Technological Determinants	
Degree of integration among MRP modules	
Source of system	
System cost	
Additional investment over next 3 years	
User class (stage of MRP implementation)	
MRP system features	
Human Determinants	
The previous experience with CAPM Systems	
Education and formal training	
User involvement	
User support	
Degree of utilising the outputs of MRP	

For analytical purposes, it should be noted that one variable in this study (i.e. degree of data accuracy) has been treated once as an independent variable, and again as a dependent variables. It can be a benefit that can be obtained from MRP implementation as suggested by Callarman and Heyl (1986) and Sum & Yang (1993), and as an implementational determinant variable of MRP benefits as in Sum et al. (1995).

4.3.3 Formulation of the research hypotheses

In pursuit of the objectives of the research, the following hypotheses have been formulated, forming the basis for the primary data collection and have been devised to guide the direction of the research and organise the survey. These hypotheses are taken from the literature sources and are presented in two levels as follows:

4.3.3.1 Benefits obtained from MRP implementation

Hypothesis # (1) "Not all MRP users in Egyptian industrial sector attain the same benefits from MRP implementation".

This hypothesis seeks to explore that there are significant differences concerning the benefits obtained from MRP implementation based on the expectations and perceptions of MRP users in Egyptian manufacturing companies. This was taken from Anderson and Schroeder (1984); and Duchessi et al. (1989).

4.3.3.2 The MRP benefit-determinant relationships [2]

Hypothesis # (2) "The explanatory variables (i.e. uncertainty, organisational, implementational, technological and human variables) do not necessarily correlate with MRP implementation benefits in a linear manner".

[2] Since the main aim of this hypothesis is to explore and examine the relationships between uncertainty, organisational, implementational, technological & human variables and the benefits obtained from MRP implementation, these relationships form 608 sub-hypotheses (32 independent variables X 19 dependent variables) each one reflects one of the relationships under investigation, it was decided to develop one main hypothesis to reflect the expected relationships instead. This will be measured using ACE model as illustrated in detail in Chapter seven.

This hypothesis attempts to test the assumption that there exist underlying non-linear relationships among determinant variables such as execution data accuracy, degree of integration among MRP modules, planning data accuracy, technical problems, company size and people support problems and the benefits obtained from MRP implementation. This hypothesis was taken from (Sum et al., 1995).

4.3.4 Identification of the population for this study

The survey population of this study was defined as all state-owned companies working in the manufacturing industry in Egypt. The sample frame used in identifying manufacturing companies for this study was taken from industrial data held by the Egyptian Industrial Chambers and the Industrialisation General Organisation. In these databases, data available includes the name of company, its address, total capital, and type of products. As a consequence, 200 companies were identified as a public manufacturing companies. Those companies constituted the total population which was targeted to be surveyed as a whole.

The main reasons for limiting the study to the industrial public sector were as follows:

a) The Egyptian manufacturing public sector contributes 75% of all industrial output within the Egyptian industrial sector, and includes all medium-to large-scale industries (Per- lind, 1991).

b) In the 80s Egyptian's manufacturing public sector generated two-thirds of the value added in industry and provides 50% of industrial employment (Kurian, 1992).

c) The examination of the literature indicates that most MRP companies are assembling and engineering manufacturing while the industrial private sector in Egypt has been limited primarily to textile manufacturing, leather products, the processing of wood products, and food processing. Therefore this sector was excluded from the study. Moreover, most of the manufacturing companies in the industrial private sector comprise individuals or small establishments rather than companies. Most of these establishments employ less than 50 people (Per-lind, 1991) and are therefore unlikely to use MRP systems.

d) Since the Egyptian government has a good database, the data required was available for research purposes, providing name and address manufacturing companies of public sector in Egypt and which represents the population of the current study.

4.3.5 Development of the questionnaire

As we mentioned in the previous section the field research was carried out by using mail questionnaire. The following steps were carried out in the development of the questionnaire:

4.3.5.1 The type of questions

Essentially, a combination of closed and open-ended types of questions was used in the current study for the following reasons:

1. Most MRP users in Egypt are relative beginners. Closed-ended questions were used whenever possible to reduce the number of ambiguous answers that might be given.

2. Since the key issue under investigation is the state of practice of MRP systems in Egyptian manufacturing companies, some opened-ended questions were used in order to make the respondents write down what they have seen fit.

Multiple-choice questions offer a number of advantages over open-ended questions. They are generally easier for the respondent and they also tend to reduce respondent bias (Tull, 1987).

A space also for additional information and documentary data was provided where relevant to be completed by the respondent.

4.3.5.2 The validity of questionnaire

The validity of a measure refers to the extent to which it measures what it was intended to measure. One of the related approaches for establishing validity for the current study is called "content validity" (Al-Shauaibi, 1991; Whitley, 1996; Nation, 1997). This approach refers to the extent to which it provides adequate coverage of the topic under investigation. There are two main methods can be used to determine "content validity".

(1) The determination of the topic under investigation and the items to be scaled. To do that, the author's selection of questionnaire items was based on an extensive review of the literature and the previous empirical studies. Then, the items in the questionnaire were scaled, on a variety of Nominal, Ordinal and Ratio scales (see the questionnaire version in Appendix A).

Table 4.1 which is adopted from Emory (1985, p. 87) shows the differences between these types of scales as follows:

Table 4. 1 Characteristics of Measurement Scales.

Type of Scale	Characteristics of Scale
Nominal	No order, distance, or origin
Ordinal	Order but no distance or origin
Interval	Both order and distance but no origin
Ratio	Order, distance, or origin

An important issue that should be flagged up here relates to utilisation of both odd and even- numbered scales. An even-numbered scale such as four or six point, has the advantage of forcing the respondents to either agree or disagree to some extent with a particular issue. An odd scale, on the other hand allows for indifferent responses (Moser and Kalton, 1971).

The second issue taken into account here related to utilising a numerical code[3] for the Ordinal and Interval data which can help to transform the responses to data values that can be directly subjected to statistical analysis (Nation, 1997).

(2) To use people to judge how well the questionnaire meets the standard. This was done as far as possible. To do that, a pilot questionnaire document was produced and pre-tested by academics and on a small number of companies, well-known to the researcher. All questionnaire items were pre-tested by Prof. Arthur Francis the supervisor of the research and some staff members of the Department of Management Studies at University of Glasgow Business School. It was also tested by 24 managers (the production manager, materials manager, inventory control manager, master scheduler, and management information system manager) of the Egyptian manufacturing public

[3] A numerical code means that the responses are data values that can be directly subjected to statistical analysis.

sector in order to ensure that each question was clear and easily understandable. Furthermore, the validity is enhanced because the data were collected from subjects in a natural setting and the sample represented a known population.

4.3.5.3 Identification of appropriate respondents

In the current study, the basic criterion for the choice of the respondents was the capability of the respondents to provide the necessary information (i.e. information to help to display the state of practice of MRP system and its effectiveness) on the basis of his/her participation in using an MRP system. Consequently, the target respondent in each company was the production manager or materials manager or inventory control manager or master scheduler or management information system manager as in Sum and Yang (1993); Ang et al. (1995) and Sum et al. (1995).

4.3.5.4 The questionnaire

In order to ensure that the questionnaire was reliable for the current study a number of steps were taken in the construction of the questionnaire. These included the replication of questions from the pioneer studies previously conducted in related fields of the study such as Duchessi et al. (1988); Sum and Yang (1993) and Sum et al. (1995), and translation of the questionnaire was another factor of reliability in this study. Because this study was conducted in Egypt where Arabic is the main language, it was necessary to translate the questionnaire into an identical version of Arabic language. To do that, the questionnaire was translated by the researcher and revised by four Arab Professors of the Department of Linguistics at the Faculty of Linguistics and Translation- Al Azhar University in Egypt.

The user questionnaire collected data on six sets of issues.

First part: General information and organisational determinant variables

This part of the survey instrument comprised fifteen questions designed to be responded to by both MRP users and non-users. The first three questions seek responses regarding the title of respondent, then the type of industry, and company's ownership (based on nominal scales). The next five questions seek responses regarding type of products, type of manufacturing, type of processes (based on nominal scales), years in operations, company size measures, the parameters of product structure complexity, and the significance of main areas used for promoting MRP systems (based on ordinal scales). Six of the first fifteen questions apply only to MRP users as they relate to MRP definitions, organisational arrangements for implementing MRP systems, the responsibility for managing the MRP project, the main reasons for implementing MRP systems, the degree of computerisation of MRP modules (based on ordinal scales), and the company's organisational willingness to change (based on a nominal scale).

Finally, the last question in this part is for non users in order to provide responses regarding the current system used and the main obstacles that impede MRP implementation (based on ordinal scales).

Second part: Uncertainty determinant variables

This part of the survey instrument is intended for MRP users in order to provide responses concerning uncertainty determinant variables that influence the benefits obtained from MRP implementation. These are: product characteristics diversity, amount of aggregate product demand, machine downtime, product quality, behaviour of people within the company, reliability of plant within the factory, and capacity constraints (based on ordinal scales).

Third part: Implementational determinant variables

This part of the survey instrument is intended to obtain responses regarding implementational determinant variables that influence MRP benefits. These are: initiator of MRP (based nominal scales), years in implementation (based on an ordinal scale), implementation strategy (based on a nominal scale), the degree of data accuracy, vendor support, and problems that impede the successful implementation of MRP systems (based on ordinal scales).

Forth part: Technological determinant variables

This part of the survey instrument seeks the responses concerning the technological determinant variables that impact on the benefits obtained from MRP implementation. These are: the features of MRP systems, the source of MRP system, user class (based on nominal scales), the costs of MRP installation, how much the company is prepared to invest further (based on ordinal scales), and finally the degree of integration among MRP modules (based on a ratio scale).

Fifth part: Human determinant variables

This part of the survey instrument is intended to provide responses regarding the human factor that influence MRP benefits. These are: the degree of involvement in the implementation, the extent of utilising the outputs of MRP system, level of support of MRP implementation, level of formal training (based on nominal scales), and the previous experiences with the automated complex information systems (based on ordinal scale).

Sixth part: MRP benefits measures

This part of the survey instrument is intended to provide responses concerning the benefits obtained from MRP implementation. Some concern tangible benefits [i.e. inventory turnover (sales/inventory ratio), delivery lead time (days), percent of time meeting delivery promises (%), percent of orders requiring "splits" because of unavailable material (%), and number of expediters (number of people)] and these are based upon the estimates of MRP users of what levels of performance were on the five measures prior to MRP implementation, after MRP implementation and in the future. Others concern subjective benefits (i.e. improved competitive position, reduced inventory costs, increased throughput, improved product quality, improved productivity, better ability to meet volume/ product change, better production scheduling, reduced safety stocks, better cost estimation, improved co-ordination with marketing and finance, improved user ability to perform in his/her job, reduced informal systems for materials management/ inventory/ production control, increased BOM accuracy, and increased information on which to base decisions since MRP has been implemented) based upon user's perceptions using an ordinal scale.

4.3.6 Identification of the appropriate method for data collection

For primary data collection by questionnaire, there are three methods that can be used, and these are Telephone survey, Mail survey, and Personal interview. Each of them has its own merits and demerits as illustrated below:

4.3.6.1 Telephone survey

This stands out as the best method for gathering information quickly. It permits the interviewer to clarify questions if they are not understood. The main drawback of telephone interview is that it is usually short because people are unwilling to talk for very long periods on the telephone (Breakwell, 1995).

4.3.6.2 Personal interview

It has been considered the most versatile of the three methods. In this method many advantages can be obtained. The personal interviewer can ask more questions, it can be long; and a high level response rate can be achieved (Kerlinger, 1986; Whitley, 1996). However, it is the most expensive method and requires more trained people for conducting the interviews (Brownell, 1995).

4.3.6.3 Mail survey

This may be the best way to reach persons who would not give personal interviews or where there might be interviewer bias. The main drawback of the mail questionnaire is its low response rate (Whitley, 1996).

However, since the exact number of companies having at least basic MRP modules such as inventory control in Egypt was not known, the primary intention of the current study was to collect data from as many companies as possible. Therefore, mail survey was chosen in preference to other two kinds of survey methods for the following reasons:

a) Since the Egyptian manufacturing companies are geographically dispersed the mail questionnaire is the appropriate technique for data collection in this study. A list of valid addressees for *200* companies representing the public manufacturing companies was identified from two main sources (Egyptian Industrial Chambers and Industrialisation General Organisation).

b) Due to one of the objectives of the current study being the investigation of the real state of practice of MRP systems in Egypt, the decision was made to use a mail survey in order to avoid any response that might be biased by the interviewers.

c) Since the respondents of the current survey are managers, making appointments with them for personal interview or talking with them via a telephone survey would be difficult. Therefore the decision was made to use mail survey method.

Only one survey questionnaire was sent to each company, to be completed whether by the production manager or materials manager or inventory control manager or master scheduler or management information system manager.

4.3.7 Response rate

Of 200 questionnaires sent out, 123 replies were received, giving a response rate of 61.5% which was regarded as a good response to mail survey. Nachmias and Nachmias stated "that the sample size must be a certain proportion (often put at 5 percent) of the population" (1992, p. 185). Furthermore, Roscoe (1975) argues that sample sizes between 30 size and less than 500 are appropriate for most research. Of the 123 replies, 93 respondents were usable: the unusable responses being because they are with a high proportion of missing values. The final usable sample (93 respondents, giving a response rate of 46.5%) was broken down into two categories of MRP users and Non users (52:41).

Table 4.2 shows the various industries represented in the responses as it is illustrated below:

Table 4. 2 Companies classified according to type of industry.

	MRP Companies		Non-MRP Companies		Overall	
Description	No	%	No.	%	No.	%
Textiles	8	15.38	11	26.83	19	20.43
Mining and petroleum industries	3	5.77	3	7.32	6	6.5
Drink and tobacco	0	0.0	3	7.32	3	3.3
Engineering & electronic	26	50.0	4	9.7	30	32.2
Garments	0	0.0	0	0.0	0	0.0
Chemicals	11	1.16	9	21.9	20	21.5
Leather	0	0.0	0	0.0	0	0.0
Wood	0	0.0	0	0.0	0	0.0
Food industries	4	7.69	6	14.6	10	10.7
Paper	0	0.0	3	7.32	3	3.3
Printing	0	0.0	0	0.0	0	0.0
Plastics	0	0.0	2	4.8	2	2.2
Total	52	100.0	41	100.0	93	100.0

It appears from Table 4.2 that some industries were more involved in implementing MRP systems than the others, e.g., engineering industries were more involved (50.0% of MRP companies). In contrast, there are several industries where no firms in the sample have implemented MRP systems, so far, such as the drink and tobacco industries and the paper industries.

On the other hand, participating respondents came from all MRP users as illustrated in Table 4.3 below:

Table 4. 3 Distribution of responses achieved from MRP users by MRP users.

Type of company	PMs*	MMs*	ICMs*	MSs*	MISMs*	Total
Engineering	15	1	3	3	4	26
Textile	2	3	0	0	3	8
Chemical	2	2	3	1	3	11
Food	1	2	0	1	0	4
Mining	1	0	1	0	1	3
Total	21	8	7	5	11	52
Rate	40.4	15.4	13.4	9.6	21.2	100.%

* PMs refers to production managers, MMs refers to materials managers, ICMs refers to inventory control managers, MSs refers to master schedulers, and MISMs management information system managers.

Table 4.3 reveals that the higher response rate came from production managers rather than others. And also, for non users Table 4.4 indicates that the high response rate came from production managers.

Table 4. 4 Distribution of responses achieved from non-MRP companies.

Type of company	PMs	MMs	ICMs	MSs	MISMs	Total
Engineering	1	0	0	2	1	4
Textile	4	2	4	0	1	11
Chemical	2	1	1	3	2	9
Food	2	2	0	2	0	6
Mining	1	0	1	1	0	3
Plastics and Metals	1	0	0	0	1	2
Paper	1	2	0	0	0	3
Drink and Tobacco	2	0	0	0	1	3
Total	14	7	6	8	6	41
Rate	34.1	17.1	14.6	19.5	14.6	100%

4.3.7.1 Increasing response rate

In seeking to increase the response rate, several ways were followed by the researcher. These were: a) personalised cover letters were used, in this case three cover letters were issued- one from the researcher's supervisor, the second one was issued by the Department of Mission- Ministry of Education in Egypt and the third one included permission to the conduct survey and was from the so-called Central Agency for Public

Mobilisation and Statistics in Egypt. These letters briefly explained the purpose of the study and its importance and requested the co-operation of the respondents,

b) using stamped rather than business reply return envelope was used. To do that, each company received one questionnaire in a sealed envelope and which contained a questionnaire and a stamped return envelope, and

c) all companies were promised strict confidentiality regarding the identity and participation in the current study.

4.3.7.2 Problems and limitations

First of all, as might the expected, not all companies whose co-operation was sought were willing to cooperate despite the personalised letters, using stamped envelope and the researcher's promise of strict confidentiality (i.e. response rate was 38.4%). In some cases a large period of time passed before the questionnaires were received (two months after). The high rate of uncompleted questionnaire (i.e. 30 out of 123 questionnaire received were unusable because they are with a high proportion of missing values).

4.3.8 Data analysis methods

Finally, for drawing the conclusion, the survey responses were coded, and then analysed by using two statistical packages that were expected to be well suited for the analysis of survey results. These were:

First, the Statistical Package for the Social Sciences (SPSS for Windows). SPSS is an integrated system of computer programs designed for the analysis of social science data. The programme provides a combined and comprehensive package which enabled us to perform different types of data analysis such as frequency, Mann-Whitney U-test, Kruskal-Wallis, 1-Way Anova and Factor Analysis.

Second, the Dbank package which can be defined as a network-ready, tree-structured filing system for data that runs under Microsoft Windows. It provides numerous commands for managing, manipulating, viewing and plotting data in a user-friendly environment. One of the main techniques for data analysis in Dbank is the Alternating Conditional Expectation (ACE) model.

The following statistical techniques were used in the current study:

- Frequency Analysis was used to show a count of the number of occurrences that fall into each of several categories, when the categories are based on two or more variables considered simultaneously such as initiator of MRP systems and level of formal training.
- Mean Value was used to provide differences between items.
- Standard Deviation was used in order to state the degree of consistency in responses among the sample companies i.e. when the Standard Deviation is low the degree of consistency is high and vice versa.
- The Mann-Whitney test and the T-test were used to find out if significant differences exist between MRP companies and Non-MRP companies.
- The Kruskal Wallis and One Way Analysis of Variance (ANOVA) were employed to find out if significant differences exist among MRP users.
- The Paired T-Test technique was used to find if significant differences exist between results of the current study and the previous studies.

- Spearman's Correlation Coefficient used to find out the strength of the relationship between company size factors and MRP installation costs.
- The Bartlett's Test of Sphericity tests if there is a large or small correlation between variables.
- The Kaiser-Meyer-Olkin (K-M-O) measure of sampling adequacy which indicates whether the overall approach of Factor Analysis is likely to be worthwhile and whether each variable is worth including.
- Principal Component of Factor Analysis was used to reduce a large number of independent variables (determinant variables affecting MRP benefits) and dependent variables (the subjective benefits obtained from MRP implementation).
- Eigenvalue criterion was used to determine the number of factors needed to represent the data.
- The Varimax rotation technique was employed to magnify the factor loadings by maximising the variance.
- Matrix Scatterplots method was used for identifying the form of the relationships between variables (i.e. there is a non-linearity or not).
- The adjusted R^2 is used as a benchmark for comparing the quality of the regression of b on d (before transformation) to the regression of tb on td (after transformation), where b is the benefit obtained from MRP implementation and d is the determinant variable.
- OLS technique was used in order to evaluate an ACE's model capability.

- Forward and Backward Stepwise strategies were used for selecting the final models for MRP benefits.
- The Skewness method was used to determine which data departed from normality.
- The Cook's Distance measure was used as an easier and more accurate way of detecting multivariate outliers.
- ACE model was used as the best overall way to represent the dependence of the dependent variable on the independent variables.

4.4 Summary

The main purpose of this chapter was to describe the design of the appropriate methodology for achieving the major objectives and answering the questions of the current research through describing the steps which are used to carrying it out. Three types of research designs (i.e. experiment, case study, and nonexperiment- survey) followed by the most common methods in the social sciences for collecting data (i.e. observation, questionnaire, interview and archival records) are presented with their own merits and demerits. The survey design was used as the most suitable approach to fulfil the objectives of the current study.

It is stressed in this chapter that there is never a single or standard perfect design or method for research because each type has its merits and demerits. However, one can conclude that the suitable design or method is one which enables the investigator to meet the research objectives.

As a consequence, the design of the current study has passed through eight successive stages. It starts with recapitulating the research questions and its objectives, outlines the overall variables underlying the structure and the main approach of the current study, presents the hypotheses have advised to guide the direction of the research and organise the survey, identifies companies among which the survey has been conducted, develops the questionnaire, determines the appropriate method for data collection, identifies sample size, and determines the appropriate data analysis methods.

The findings of the survey and analysis of the results are given in the next three chapters (Chapters 5,6 & 7).

CHAPTER FIVE

Data Analysis

Current MRP Practices in Egypt

5.1 Introduction

Since MRP implementation is relatively new in less developed countries such as Egypt, there is no research that considers MRP implementation in Egypt or in any developing country. This may stem from a lack of knowledge about MRP systems in less developed countries in general, and in Egypt in particular. This chapter of the study is intended to:

1. Investigate MRP practices in Egyptian manufacturing companies which may be educational and informative for manufacturing companies which have implemented, are implementing, or are considering MRP implementation.
2. Identify the similarities and dissimilarities of the nature of MRP implementation in Egypt compared to other contexts.

In pursuit of these objectives, this chapter presents the analysis of the field study findings concerning the survey of both MRP-companies and non MRP-companies. Ninety-three responses were received, of which fifty-two were from MRP companies which operated in quite different business environments within the Egyptian industrial sector. Data from these were investigated and compared with findings from previous studies elsewhere such as: Sum and Yang (1993) in Singapore as a newly industrialising country, and Anderson et al. (1982) and Laforge & Sturr (1986) in the US as a developed country.

Statistical techniques used in analysing the data collected from the field study are arranged as follows:

- The presentation of the basic distributional characteristics of the variables through frequencies and percentages.
- To find out if significant differences exist between MRP companies and Non-MRP companies the Mann-Whitney test and the T-test were used (for double accuracy).
- To find out if significant differences exist among MRP users the Kruskal Wallis and One Way Analysis of Variance (ANOVA) were employed.
- The Paired T test was used to find out if significant differences exist between results of the current study and the previous studies.

To ascertain the state of practice of MRP implementation in Egypt, the data collected in the survey of Egyptian manufacturing companies are presented and discussed in nine sections as follows: the second section shows company profile; the third section states the main obstacles that impede non-MRP companies to implement MRP systems in Egypt; the fourth section presents the importance of various factors in promoting MRP in Egypt; the fifth section presents the main reasons for implementing MRP systems from the point of view of MRP users; the sixth section shows the organisational arrangements for implementing MRP systems; the seventh section states MRP implementation process; the eighth section deals with MRP systems characteristics; the ninth section shows MRP user's profile; the tenth section deals with the stage of MRP implementation which includes the type of industry and uses an MRP classification profile.

Finally, this chapter of the research is concluded by providing an assessment of the state of practice of MRP systems within Egyptian manufacturing companies.

5.2 Company profile

This section is intended to present the main features of the companies sampled in this survey. These will be compared with the previous studies whenever possible and meaningful.

5.2.1 Type of industry

As mentioned earlier in Chapter 4 (see section 4.3.7), some industries implemented MRP systems more than others, e.g., engineering industries accounted for 50.0% of the MRP companies. In contrast, there are several industries which have not implemented MRP systems, so far, such as the drink & tobacco industries and the paper industries.

Similar studies by Anderson et al. (1982) concluded that electric and electronic industries had achieved the highest proportion of MRP implementation in the US, while Sum and Yang (1993) reported that 47.5% of MRP companies in Singapore were located within the electronic and transport equipment industries. These sectoral differences may be influenced by the fact that Singapore and USA have very different industrial profiles.

5.2.2 Company characteristics

The findings in Table 5. 1 indicate that the majority of MRP companies are governmental owned in contrast to Sum & Yang (1993) study which indicates that 59.3% of MRP companies in Singapore are multinational corporations. This reflects a feature of the Egyptian economic structure where a large public sector has been dominating control over the industry (Per-lind, 1991; DTI, 1996). Respondents indicated that MRP systems are more likely to be found in older companies. The interpretation of this finding is that when the company becomes mature and more established, it is more willing to invest in longer term enhancement projects such as MRP systems (Sum and Yang, 1993).

The majority of MRP companies embraced a marketing strategy combination of make to order and make to stock products. This is a similar trend in relation to marketing strategy which MRP companies used in the US and Singapore as demonstrated by Anderson et al. (1982) and Sum & Yang (1993) respectively.

MRP systems are also more often adopted by manufacturing companies that work in complicated manufacturing processes (assembly and fabrication operations) than in companies with continuous/process flow. To a large extent, this result is similar to those of Anderson et al. (1982) and Sum and Yang (1993) concerning the type of manufacturing associated with the implementation of MRP systems by American and Singaporean manufacturing companies, successively.

Furthermore, our findings concur with the findings of Cerveny and Scott (1989) study, Burns et al. (1991) study and Sum and Yang (1993) study, concerning the type of process (layout) associated with MRP implementation by the American and Singaporean users. It indicates that MRP users are likely to be assembly line (i.e. layout by product) and job shop (i.e. layout by process) more than non-users.

Table 5. 1 Company characteristics reported by the total sample.

Characteristic	MRP Companies (N)	MRP Companies (%)	Non- MRP Companies (N)	Non- MRP Companies (%)	Overall (N)	Overall (%)
Ownership*						
Government	48	92.3	39	95.1	87	93.5
Private	0	0.0	0	0.0	0	0.0
Multinational corporation	4	7.7	2	4.9	6	6.5
Total	52	100.0	41	100.0	93	100.0
Age*						
Less than 3 years	0	0.0	0	0.0	0	0.0
4-5 years	2	4.0	3	7.3	5	5.5
6-10 years	1	2.0	8	19.5	9	9.9
11-15 years	8	16.0	11	26.8	19	20.8
More than 15 years	39	78.0	19	46.3	58	63.7
Total	50	100.0	41	100.0	91	100.0
Type of products*						
Make-to-order only	11	22.4	15	36.6	26	28.8
Make-to-stock only	11	22.4	8	19.5	19	21.1
Make-to-order and make-to-stock	27	55.2	18	43.9	45	50.0
Total	49	100.0	41	100.0	90	100.0
Manufacturing process*						
Assembly only	4	7.6	3	7.7	7	7.7
Fabrication only	1	1.9	2	5.1	3	3.3
Assembly and fabrication	29	55.8	19	48.7	48	52.7
Continuos/process flow[1]	18	34.6	15	38.5	33	36.3
Others	0	0.0	0	0.0	0	0.0
Total	52	100.0	39	100.0	91	100.0
Layout(type of process)*						
Job shop	14	27.5	5	13.9	19	21.8
Continuos process[2]	6	11.8	18	50.0	24	27.6
Assembly line	31	60.8	13	36.1	44	50.6
Combination	0	0.0	0	0.0	0	0.0
Total	51	100.0	36	100.0	87	100.0

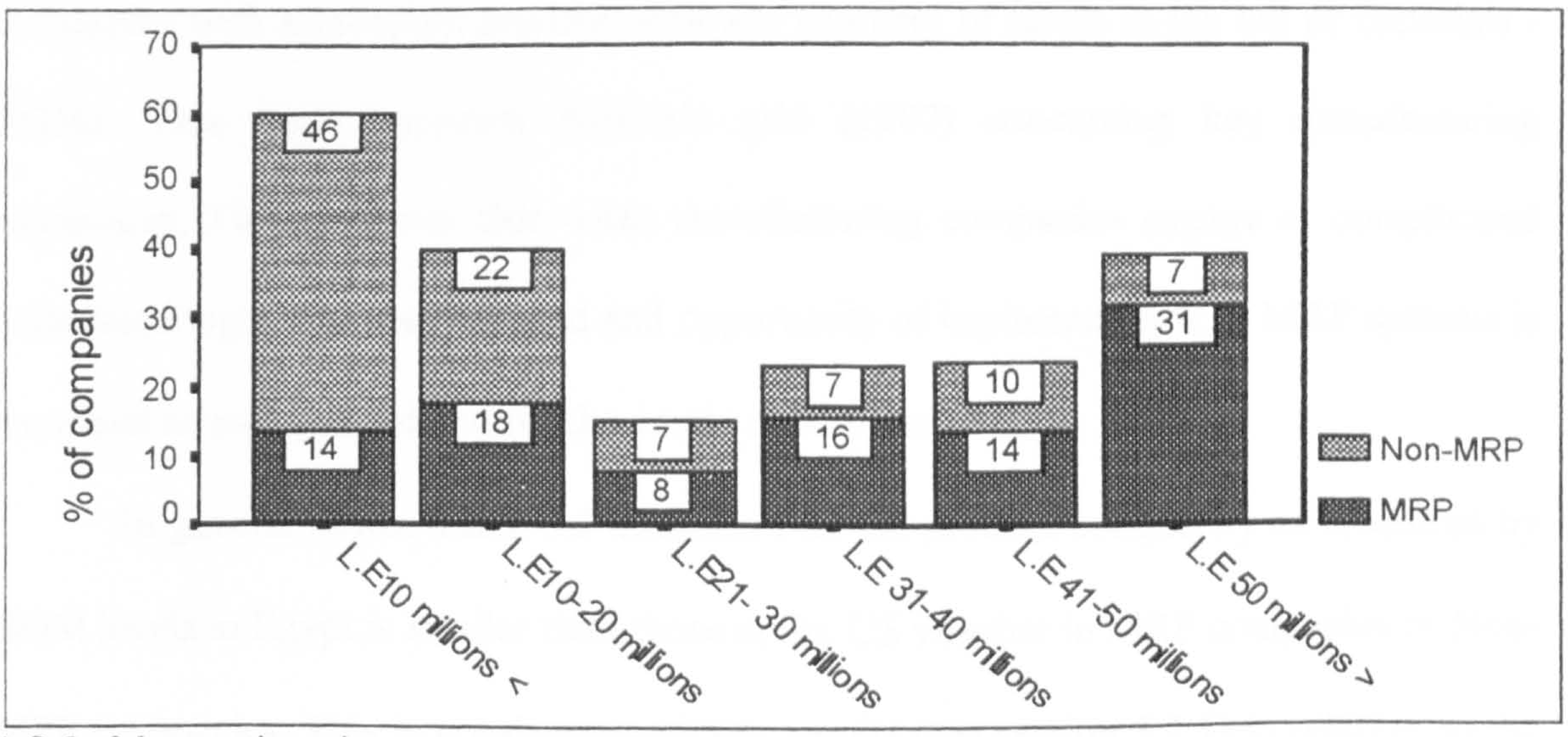
* Q 3 of the questionnaire
** Q 4 of the questionnaire

[1] As on assembly lines, production follows a predetermined sequence of steps, but the continuos/process flow is continuos rather than discrete as in petroleum and chemicals industries. Such structures are usually highly automated and constitute one integrated "machine" that must be operated 24 hours a day to avoid expensive shutdowns and start-ups (Chase et al., 1998).

[2] Continuos process means layout by product for companies have machines that must be operated 24 hours a day such as petroleum and chemicals companies.

5.2.3 Company size

Figure 5. 1 1995 Gross sales*.



* Q 5 of the questionnaire

It seems from Figure 5.1 that MRP implementation is inclined to increase as one moves from small companies with gross sales less than L.E. 10 millions to big companies with gross sales greater than L.E 50 millions. This result supports the results ofAnderson et al. (1982) study, and Sum and Yang (1993) study, which concluded that as companies increase in size as measured by gross sales, they have a greater inclination to implement MRP systems (i.e. to computerised systems).

Furthermore, Table 5.2 indicates that MRP systems as measured by number of employees and number of production and inventory control employees are more adopted by large companies in both the Egyptian and American companies.

Table 5. 2 Number of employees and production & inventory control employees (Mean values) in different contexts.

Study	Number of employees in		Number of P & I C employees in	
	MRP companies	Non-MRP companies	MRP companies	Non-MRP companies
The Current study*	2,100	1,011	48	26
Anderson et al., study	1,064	578	19	12.5

* Q 5 of the questionnaire

5.2.4 Product complexity

Table 5.3 suggests that MRP systems are more often adopted by manufacturing companies with a complex product structure (number of levels in the bill of materials - BOM). This result supports Puttick's grid (1987) concerning key manufacturing techniques. This supposes that when manufacturing companies engage in complicated manufacturing processes, the need and opportunity of implementation of MRP systems is increased to manage and control the whole operations.

In general terms, Table 5.3 indicates that the product complexity as measured by BOM levels in Egypt is smaller than those in the US whether in MRP companies or Non-MRP companies. This is consistent with our results (see section 5.2.1) in relation to the fact that MRP companies in the US have very different industrial profiles.

Table 5. 3 Number of Bill of Materials levels (Mean values) in different contexts.

Study	BOM levels in MRP companies	BOM levels in Non-MRP companies
The Current study*	4.4	2.3
Anderson et al., study	6.9	5.8

* Q 6 of the questionnaire

Furthermore, our findings indicate that the majority of MRP companies (51.0%) reported that number of items per product are over 100 items. This result supports the findings of Anderson et al. (1982), who found that the MRP systems have been implemented by companies with a complex product structure measured by the number of the parts and components per product. In the same trend, this finding concurs with Sum et al. (1993) study, who reported that as the number of parts per product increases (more than a 40- part), the product structure becomes bigger and more complex.

5.3 Obstacles that impede MRP implementation in Egypt

Our findings indicate that about 44.1% of companies participating in the empirical study had not implemented the MRP systems. They reported that the traditional systems (Reorder Point Systems- ROP) have been used for manufacturing planning and control for more than 5 years. To some extent, this result concurs with the findings of Newman & Sridharan (1992), who found that 59 out of 185 manufacturing companies surveyed in the US still implemented the Reorder Point Systems- ROP- computer based or manual.

Lack of knowledge about MRP was reported as the biggest obstacle impeding MRP implementation for non-adopters (Table 5.4), with a high level of agreement between respondents about this (SD .27). To a large extent this result is similar to Ang et al. (1995), where they found that the main reason for not implementing MRP systems is a lack of company expertise in MRP in Singaporean companies.

Table 5. 4 The main obstacles that impede MRP implementation reported by non-MRP companies*.

Item	Mean score**	SD***
Limited knowledge about MRP	2.92	.27
Successful without MRP implementation	2.50	.73
Not applicable	1.82	.39
Not felt to achieve big enough benefits	1.69	.47
Cost too high	1.21	.41
Potential staff attitude problems	1.08	.37

* Q 15 of the questionnaire ** Based on a 3-point scale "1" for of no significance and "3" for very significant.*** The standard deviation presents an adverse measure of agreement among the respondents which means that a high standard deviation refers to a low level of agreement while a low standard deviation indicates a high level of agreement (as in White and Wharton, 1990).

To find out if there were significant differences between industrial sectors in the reasons given by non-MRP companies, for non-adoption, the Kruskal Wallis and One Way Analysis of Variance (ANOVA) were used. These techniques indicate that there is no significant difference between industries concerning the issue under investigation (see Table 5.3.1 in Appendix B).

5.4 Factors promoting MRP systems

Table 5.5 indicates that the Egyptian government support (e.g., grants, incentives), and education/training provided by government and vendors were regarded as very important by all companies in the sample in promoting use of MRP systems. This finding is extremely important for industrial policy in the light the findings of Per-lind (1991), about computerisation in less developed countries with especial application to El Nasr company in Egypt. He said that the industrialisation programme is a major development strategy in Egypt, as in many less developed countries but is faced with several problems and obstacles of an economic, organisational, technical nature. The Egyptian government has tried to overcome these problems in several ways (e.g., computers have been adopted for the support of specific key functions such as Material Requirements Planning (MRP) systems).

Table 5. 5 Factors promoting MRP in Egypt*.

Item	Mean score**
Government Support (e.g., grants, incentives)	4.82
Education/training provided by government	4.51
Education/training provided by software/hardware vendors	4.45
Information sharing among users	2.12
Low cost consultancy	1.27

* Q 7 of the questionnaire.
** Based on a 5-point Likert scale "1" for not important and "5" for extremely important.

Both Mann-Whitney test and the T-test techniques indicated that there is no significanct difference between MRP companies and non-MRP companies concerning this issue (see Table 5.4.1 in Appendix B).

Compared with Ang et al. (1995) concerning the importance of factors promoting MRP in Singapore, the results in the current study and Singaporean study are to a large extent similar concerning the importance of government's role in introducing MRP into the Egyptian and Singaporean companies.

5.5 Reasons for implementing MRP systems

It appears from Table 5.6 that lower inventory cost and meeting delivery dates better were the most important reasons for implementing MRP systems in Egypt and Singapore. Apparently, MRP users whether in Egypt or Singapore did not feel that improving the quality of products was an important reason for implementing MRP systems.

In the aggregate, one can say that the reasons for MRP implementation are tactical and not strategic reasons in the two studies. The Paired T-Test technique revealed that there is no significant differences between the two studies (see Table 5.5.1 in Appendix B).

Table 5. 6 The reasons for implementing an MRP system in different contexts*.

Reason	Current study	Sum & Yang study
Lower inventory cost	4.69**	4.06
Meet delivery dates better	4.63	4.25
Inventory control	4.10	3.74
Improve competitive position	3.39	3.74
Production control	2.88	3.91
Improve productivity	2.62	3.98
Increase throughput	2.61	3.60
Improve quality of products	2.53	2.77

* Q 12 of the questionnaire ** Based on a six-point Likert scale, score "0" for not at all; "1" for weak reason and "5" for strong reason.

5.6 Organisational arrangements for MRP implementation

It appears from Table 5.7 that two-thirds of MRP companies set up a formal steering committee to oversee the implementation of MRP system, and in half the cases it met at least once a month and a project team met weekly. MRP companies in Egypt set up a formal steering committee to oversee the implementation of MRP systems more than their peers in Singapore {68.8% in Egypt against 47.4% in Singapore as in (Ang et al., 1995)} but these arrangements were less formal than those made by MRP companies in the US (69.35% as in (Duchessi et al., 1988).

Table 5. 7 Organisational arrangements for implementing MRP systems reported by MRP users*.

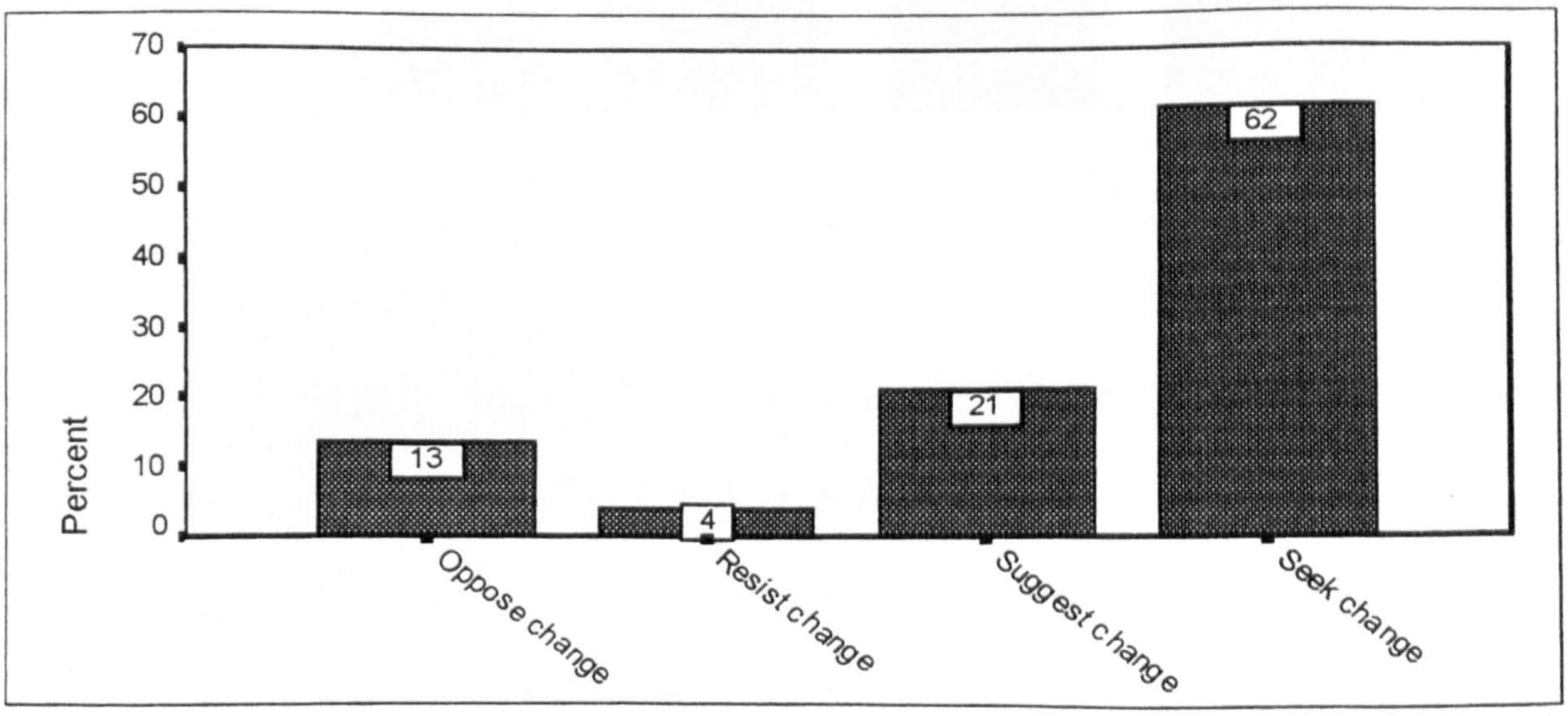
Item		Yes	No	Total
A steering committee was formed	N	33	15	48
	%	68.8	31.2	100.0
A steering committee met at least once a month	N	27	23	50
	%	54.0	46.0	100.0
The project team generally met weekly	N	26	23	49
	%	53.1	46.9	100.0

* Q 11 of the questionnaire

MRP users were asked to evaluate whether the MRP project manager's only responsibility was for managing the project or not based on Five-point Likert scale with strongly disagree =1 and strongly agree = 5. They reported that there is a strong inclination within the MRP companies in Egypt that the project manager is responsible only for managing the project whereas the mean value is (4.14). This result concurs with the findings of Burns et al. (1991), who found that 95 out of 238 manufacturing companies in the US have appointed project manager's whose only responsible for managing the MRP project.

Duchessi et al. (1989) reported that successful and less successful companies had a moderate inclination towards having the MRP project manager with a full responsibility for managing the project (the mean of their responses based on the same scale was 2.71). Furthermore, a review of the literature revealed that the organisation's willingness to change has been considered as a critical factor for implementing MRP systems by manufacturing companies (Wacker et al., 1977; Kneppelt, 1981). The respondents were also asked to indicate the organisation's willingness to implement the MRP systems. This is illustrated in Figure 5.2 below:

Figure 5. 2 Organisational willingness to implement MRP systems reported by MRP users*.



* Q 14 of the questionnaire

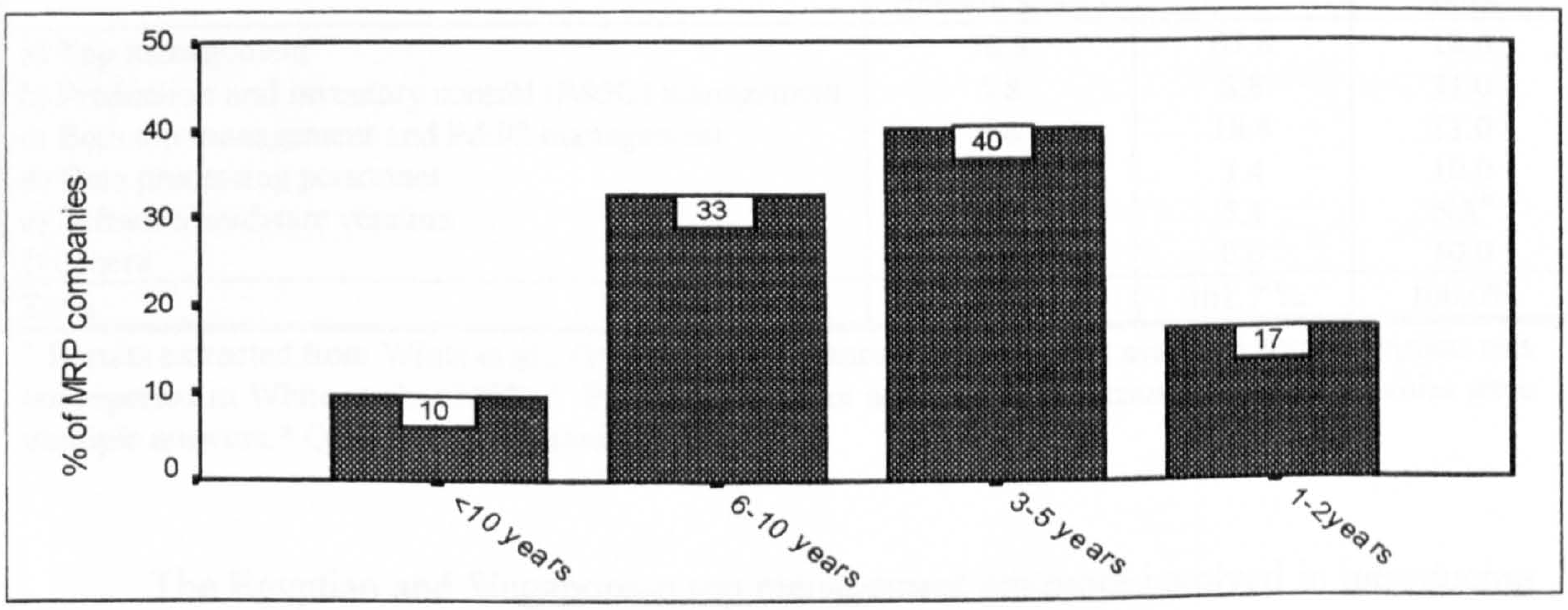
This shows that the majority of MRP companies (83.0%) were suggesting and actively seeking to implement an MRP system within the Egyptian manufacturing sector. This finding supports the findings of Burns et al. (1991), who reported that the majority of MRP companies in the US were also suggesting and actively seeking to implement the

MRP systems. They added that when the organisation's willingness to change increases, the opportunity for the successful implementation of MRP systems appears to increase.

5.7 MRP implementation process

5.7.1 Years in implementation

Figure 5. 3 The growth of MRP users in Egypt*.



* Q 18 of the questionnaire

This shows a sharply growing trend in the implementation of MRP systems by Egyptian manufacturing companies in the last decade. Implementation has been relatively recent- 57% within last five years. There has been increasing Egyptian government support for implementing new production technology within the Egyptian industrial sector, such as grants, and education provided. To a large extent, the previous result is similar to Sum & Yang (1993), concerning the degree of growth of MRP systems, and the government's role in introducing MRP systems in Singapore.

5.7.2 Initiator of MRP effort

For comparative purposes, the findings in our study are compared with White et al. (1982) and Sum & Yang (1993) studies concerning the initiator of MRP systems in the US and Singapore respectively, as shown in Table 5.8 below:

Table 5. 8 Initiator of MRP effort in different contexts (% of companies)*.

Initiator	Egypt (present study)	Singapore	United States[a]
a) Top management	78.8	67.8	18.0
b) Production and inventory control (P&IC) management	5.8	6.8	31.0
c) Both top management and P&IC management	9.6	18.6	31.0
d) Data processing personnel	0.0	3.4	10.0
e) Software/hardware vendors	3.8	5.1	NA[b]
f) Others	0.0	0.0	10.0
Total	100.0%	101.7[c]%	100.0%

[a] Results extracted from White et al., (1982). [b] "NA" means response is not available because option was not reported in White et al., (1982). [c] Percentages do not add up to 100 because several companies gave multiple answers.* Q 17 of the questionnaire.

The Egyptian and Singaporean top management are more involved in introducing MRP systems into their companies than their peers in the US companies. This result can be interpreted in the light of the fact that MRP users in Egypt and Singapore are relatively beginners compared with the US users. In turn, this may mean that the top managers are more informed about implementing MRP systems in Egypt and Singapore than their peers in US companies. On the other hand, the findings indicate that software/hardware vendors do not take any particular initiatives to promote their products though this type of application is general requires substantial support before and after its installation. This result validates Per-lind (1991) findings concerning the missing role of the computer suppliers and software vendors to promote their industry products in Egypt.

5.7.3 Degree of data accuracy

A review of the literature reveals that the company must have accurate records in the supporting files, such as BOM and inventory records, to implement MRP systems (Dilworth, 1993). Table 5.9 exhibits the findings in Anderson and Schroeder, study (1982) alongside our responses concerning the importance of the degree of data accuracy of the supporting files associated with the implementation of MRP systems.

Table 5. 9 The importance of the degree of data accuracy reported by MRP users in different contexts*.

MRP System Element	**Egypt* (current study)**	**United States**
Master production schedule	3.14**	2.7
Bill of material records	3.00	3.2
Inventory records	2.86	2.7
Vendor lead times	2.85	2.5
Production lead times	2.80	2.6
Market forecasts	2.78	2.0
Shop floor control data	2.76	2.0
Capacity data	2.75	2.0
Routing/workcentre data	2.65	NA[a]

[a] NA, means response is not available because option was not reported in Anderson and Schroeder study, (1982).* Q 20 of the questionnaire.** Based on Four-point scale, score "1" for little. "4" for very much. [c]The higher the mean, the greater the importance of the item.

It appears from Table 5.9 that the Egyptian companies with MRP systems reported the significance of data accuracy for MRP implementation, especially the three main inputs of MRP systems and which must be very accurate for sufficient application of MRP systems, namely, master production schedule, bill of material (BOM) records and the inventory master computer record respectively. This finding may mean that MRP companies in Egypt have perceived the importance of data accuracy as a critical variable for operational use as in (Anderson et al., 1982; Duchessi et al., 1989, and Sum et al., 1995).

The Kruskal Wallis Test and One Way of Variance (ANOVA) indicate that there is no significant differences among MRP users in Egypt concerning the importance of the accurate data of MRP system elements as a main pre-implementation prerequisite (see Table 5.7.1 in Appendix B).

It seems from Table 5.9 that the accuracy of BOM record element was more important in US companies with MRP systems than the Egyptian users. This result can be interpreted in light of the fact that the US users are more mature users of MRP systems (Etienne, 1983).

The pattern of responses for the other MRP elements between Egyptian and US users indicate that the accuracy of all MRP systems elements in Egypt are generally felt to be more important than in US. This result can be interpreted in light of the fact that the MRP companies in Egypt are still within a "crusade" or diffusion era of the implementation of MRP. Managers are particularly interested to get the accurate information for all MRP systems elements. This is consistent with our findings in section 5.7.1 which indicates that there is a sharply growing trend in MRP implementation by Egyptian manufacturing companies.

The Paired T-Test technique (see Table 5.7.2 in Appendix B) reveals that the difference between the two studies is statistically significant, where MRP users in Egypt have perceived the importance of data accuracy as a major prerequisite for implementing MRP systems more than their peers in the US.

5.7.4 Degree of vendor support

For comparative purposes our findings were compared with the Duchessi et al, study (1988) concerning the role of vendor support in implementing MRP systems by manufacturing companies, as it is depicted in Table 5.10 below:

Table 5. 10 Vendor support reported by MRP users in different contexts*.

Vendor Support	**Egypt**	**United States[a]**
We expected more extensive vendor support	4.89**	3.15
Vendor instructions understand their software product	4.80	3.41
The vendor provided conversion of our data into the new system	4.18	2.3
We experienced a vendor software support discontinuation problem	4.13	2.40
Vendor personnel efficiently resolved software problems	4.07	3.11

[a] Results extracted from Duchessi et al, study (1988). ([Mean of successful respondent + Mean of successful respondent]/2).* Q 21 of the questionnaire** Based on a five-point Likert scale, score "1" strongly disagree; "5" for strongly agree.

Table 5.10 indicates that the Egyptian users depend upon vendor support for implementing MRP systems more than US users. This result can be interpreted in light of the fact that many Egyptian users are relatively beginners while the most of the US users have implemented MRP systems since 1970_s. Consequently, they expect less support and rely on internal experience to solve many of the problems that they encounter during MRP implementation.

The Kruskal Wallis Test and One Way of Variance (ANOVA) techniques revealed that the differences among the five industries concerning the importance of software/hardware vendor support for implementing MRP systems are not statistically significant(see Table 5.7.3 in Appendix B).

Using the Paired T-Test technique reveals that the differences between the current study and Duchessi et al study are statistically significant in favour of the US users (see Table 5.7.4 in Appendix B). This result supports the previous findings, namely, the Egyptian users expect more support and rely on external experience to solve problems that encounter them during the implementation of MRP systems.

5.7.5 MRP implementation strategy

Table 5. 11 The implementation strategy used by the Egyptian manufacturing companies*.

Conversion Strategy	N	%
Direct Conversion	0	0.0
Phased Conversion	6	12.0
Pilot Conversion	31	59.0
Parallel Conversion	15	29.0
Total	52	100.0

N=52 * Q 19 of the questionnaire.

This shows that the majority of MRP companies in Egypt (59%) have been following a pilot implementation strategy for implementing MRP systems. This is a good sign reflecting that manufacturing companies in Egypt are aware of the importance of introducing a new technology based on a pilot approach, not only to know to what extent the people will be familiar with the new system but also in order to reduce the results derived from the failure of the implementation. This result does not concur with Burns et al. (1991) findings regarding the implementation of MRP II by 80% of the American users using a phased strategy.

5.7.6 MRP implementation problems

For comparative purposes, our findings are displayed alongside Sum & Yang (1993), as illustrated in Table 5.12 below:

Table 5. 12 MRP implementation problems[3] reported by MRP users in different contexts*.

Problem	Egypt (Current Study)	Singapore
Poor training/education on MRP	4.92**	3.02
Lack of company expertise in MRP	4.84	3.00
Lack of communication	4.75	2.86
Lack of clear goals for MRP effort	4.58	NA
Lack of involvement from vendor	4.57	2.53
A lack of support from top management	4.52	NA[a]
Lack of suitability of hardware	3.98	NA
High cost of an MRP system	3.69	2.49
Lack of support from production	3.69	NA
Lack of support from supervisor/foreman	3.67	NA
Lack of information technology expertise	3.53	2.52
Lack of support from marketing	1.92	NA
Lack of support from finance	1.90	NA
Lack of suitability of software	1.70	2.62
Lack of vendor knowledge on MRP	1.63	NA

[a] NA, means response is not available because option was not reported in Sum and Yang study.* Q 22 of the questionnaire ** Based on a five-point Likert scale, score "1" weak problem; "5" for strong problem.

The major implementation problems are poor training/education on MRP and lack of company expertise in MRP, respectively. This supports the literature review concerning the need to design MRP education and training programmes and which reflect the important ingredients of MRP implementation (Plossl, 1995; Correll, 1994). Both studies revealed that the cost of MRP systems and the lack of support from top management were not cited as major obstacles for MRP implementation.

Using Kruskal Wallis Test and One Way of Variance (ANOVA) reveal that the differences among the five industries concerning the critical factors cause obstacles or

[3] Two main implementation problems were excluded (i.e. poor data accuracy and poor user discipline). Because they have been discussed in another subsections in this chapter (see sections 5.7.3 and 5.9.1 respectively).

problems during the implementation of MRP systems are not statistically significant (see Table 5.7.5 in Appendix B).

The Paired T-Test technique indicates that there is a significant difference between the two studies in support of the Singaporean users (see Table 5.7.6 in Appendix B).

Table 5.12 illustrates that all but one of the critical factors causing obstacles or problems during the implementation of MRP systems for the Egyptian manufacturing companies are more serious than those which Singaporean users encountered. This may be because most of Singaporean users are multinational companies (Sum & Yang, 1993) which means that there is in - company expertise to help them to overcome the implementation problems.

5.8 MRP system characteristics

5.8.1 Definition of MRP

The majority of the Egyptian users indicate that the MRP system is regarded as a tool for planning and control for production (Table 5.13). In contrast, Sum and Yang (1993) reported in their study about MRP practices in Singapore that the majority of MRP companies had apprehended the extensive scope of MRP systems. This result suggests that MRP users in Egypt do not understand the extensive scope of MRP systems and which may stem back to the fact that about two-thirds of MRP companies had implemented MRP I, while only 34.7% had implemented MRP II (Q 9 of the questionnaire).

Table 5. 13 Definition of term "MRP" reported by MRP users in different contexts* (% of companies).

Definition	Egypt N	Egypt %	Singapore N	Singapore %
(a) Computerised materials/production planning and control system for production only	30	58.0	10	17.2
(b) Primarily computerised materials/production planning and control system integrated with other business area to achieve a total business system	14	26.0	40	67.2
(c) General system for computerising any business function	8	16.0	7	12.1
(d) Others	0	0.0	2	3.5
Total	52	100.0	59	100.0

* Q 10 of the questionnaire

5.8.2 MRP system features

For comparative purposes, the findings in Sum and Yang (1993) and Anderson et al. (1982), are displayed alongside our findings, as illustrated in Table 5.14 below:

Table 5. 14 MRP system features in different contexts*.

Feature	Description	Egypt (present study)	Singapore	United States
a) Update method	Net change	54.0%	32.0%	30.3%
	Regenerative	30.0%	24.0%	69.7%
	Both	16.0%	44.0%	NA[a]
b) Use of cycle counting	Yes	68.6%	75.5%	61.4%
	No	31.4%	24.5%	38.6%
c) Use of pegging	Yes	74.5%	80.9%	55.1%
	No	25.5%	19.1%	44.9%
d) MPS update frequency	Weekly	51.0%	41.5%	56.7%
	Daily	15.7%	28.3%	16.4%
	Others	33.3%	30.2%	27.0%
e) Allocation of inventory	Yes	58.0%	NA	71.3%
	No	42.0%	NA	28.7%
f) Use of automatic lot sizing	Yes	5.9%	0.0	44.5%
	No	94.1%	100.0%	55.5%
g) Time bucket size	Daily	33.3%	30.3%	NA
	Weekly	51.0%	55.4%	70.4%
	Monthly	3.9%	NA	12.5%
	Others	11.8%	14.3%	27.0%
h) Average number of weeks in MPS		29.8	22.8	40

[a] NA, means response is not available because option was not reported in Singapore and US studies.
* Q 23 of the questionnaire

Table 5.14 illustrates that most Egyptian users update their systems on a weekly basis using Net change method, while most MRP companies in Singapore update their systems on a weekly basis but using Net change and regenerative methods together. On the other hand, most US users update their systems on a weekly basis using regenerative method. This may stem from the fact that most manufacturing companies update their systems on basis of their product lead time which is likely to be different from one user to other.

Also, this is a healthy sign as it suggests that most Egyptian users understand the two methods for coping with nervousness, because, often, MRP users start with regeneration, because it is easier to understand and implement than net change (Plossl, 1995).

To a great extent, the features of the MRP systems in the three studies are similar whereas the update method is regenerative rather than Net change, employing cycle counting, higher percentage of pegging, updating MPS on a weekly basis, employing allocation of inventory, an automatic lot sizing unused, planning in weekly time bucket and the MPS planning horizon averaged ranged from 22.8 to 40 weeks.

The finding that MRP companies are extensively using cycle counting as in McCormick and Martino study (1981); Duchessi et al. (1989) and the current study, indicate that formal physical controls were used to achieve and maintain high levels of data accuracy of an inventory store. In addition, the finding that MRP companies highly emphasise the pegging feature in the three studies indicate that the MRP users have the ability to trace an item from record to another i.e. the planner can trace the demands to their ultimate sources (Plossl, 1995).

The Paired T-Test technique was employed to find out if statistically significant differences exist between the current study and the previous two studies (see Table 5.8.1 in Appendix B). The results indicate that there is no significant differences whether between the current study and the US study, or between the current study and Singapore study, or between the US study and Singapore study concerning the common features of MRP systems.

5.8.3 Hardware and software

The findings in Table 5.15 indicate that 70.6% of the MRP systems run on microcomputers and mainframes while 29.4% of MRP users run their systems on minicomputers. 84.3% of MRP companies in Egypt prefer to buy turn-key systems against 15.7% of MRP companies who did some in-house development of the bought software package. Furthermore, a majority of companies (88.2% %) indicate that the maintenance of MRP software is done by the software vendors. This result may stem from the Egyptian users seeking to take advantage of the services offered by vendors and to shorten the implementation time.

This result to a large extent is similar to the findings of the Sum & Yang (1993) study, which found that 49.2% of the MRP systems in Singapore run on minicomputers, 71.1% of MRP companies source their MRP software from vendors, and only 13.6% develop the entire software in house.

Table 5. 15 Hardware and software of MRP systems reported by MRP users of the total sample*.

Item	Egypt (present study) N**	%
Computer hardware		
Microcomputers and mainframes	38	70.6
Minicomputers	14	29.4
Source of MRP software package		
Developing the entire software package in-house	8	15.7
Buying turn-key systems	44	84.3
The maintenance of MRP software		
a. Done in-house	6	11.8
b. Done by software vendor	46	88.2
c. Done by IT specialists	0	0.0

* Q 24 of the questionnaire ** N= 52

5.8.4 Degree of computerisation of MRP modules

The findings in Sum and Yang (1993) are displayed alongside our findings in Table 5.16 below:

Table 5. 16 Degree of computerisation of MRP modules in different contexts*.

Module	Egypt (Current study)	Sum & Yang Study
Inventory control	4.29**	4.26
Purchasing and receiving	4.22	3.74
Bills of materials	4.06	4.18
Material requirements planning (parts explosion)	4.02	3.57
Customer order service	3.06	NA[a]
Routing/work centres	2.06	2.98
Sales order processing	2.06	3.18
Cost accounting	2.04	3.20
Master production scheduler	1.87	2.56
Shop floor control	1.82	2.12
Financial analysis	1.80	2.73
Payroll/human resources	1.72	2.61
Rough-cut capacity planning	.96	1.27
Forecasting	.92	1.31
Operations scheduling	.88	1.79
Capacity requirements planning	.83	1.53

* Q 13 of the questionnaire

** Based on a six-point Likert scale, score "0" for "not at all", "1" for 1-20%;"5" for "81-100%".

On the whole, Table 5.16 illustrates that the degree of computerisation of MRP modules associated with the MRP implementation in Egypt and Singapore extends only to basic MRP modules such as an inventory control, purchasing and receiving, bill of materials, and material requirements planning (parts explosion).

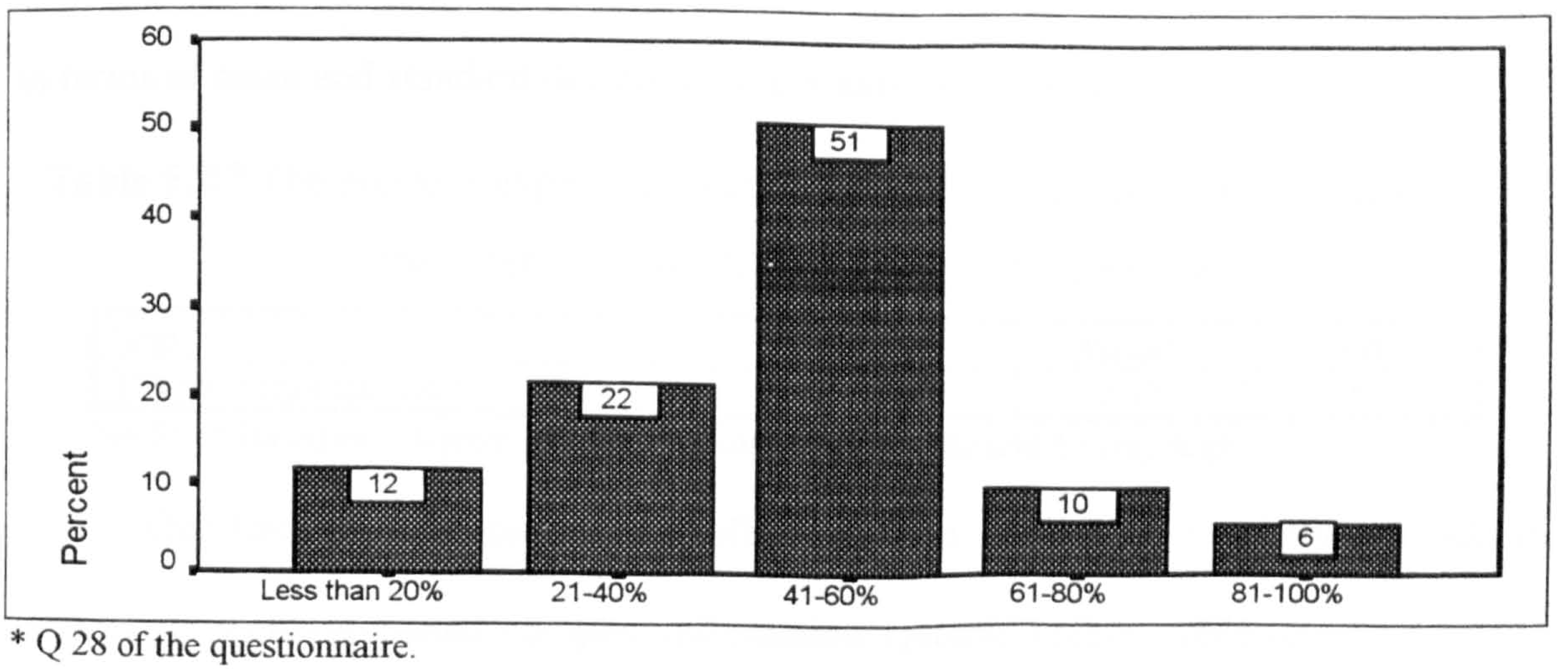
The sophisticated modules such as capacity requirements planning and rough-cut capacity planning were little used. This result can be interpreted in light of the fact that both the Egyptian and Singaporean users (Ang et al. 1995) are still relatively beginners with the implementation of MRP systems. Consequently, this degree of computerisation meets their requirements for the current period.

Using Kruskal Wallis Test and One Way of Variance (ANOVA) reveal that the differences among the five industries concerning the degree of computerisation of MRP modules in the Egyptian industrial sector are not statistically significant (see Table 5.8.2 in Appendix B).

The Paired T-Test technique indicate that there is no significant differences whether between the current study and Singapore study, concerning the degree of computerisation of MRP modules (see Table 5.8.3 in Appendix B).

5.8.5 Degree of integration

Figure 5. 4 The degree of integration among the MRP system modules rating's MRP users*.



* Q 28 of the questionnaire.

Figure 5.4 shows the extent to which companies had integrated of the elements of the MRP system listed in Table 5.16. This shows that the majority of MRP companies in Egypt (51.0%) reported a degree of communication among MRP modulesranged from 41.0-60.0%. Only 6.0% of MRP companies indicated that 80.0% or more of their computerised modules are fully integrated. This is similar to the findings of the Sum & Yang study (1993) which found that 65.0% of 59 companies had integrated at least 60.0% of these modules.

This indicates that the degree of integration among the MRP modules concurs with the length of time of MRP implementation, because of our findings indicate that MRP companies in Egypt are still relatively beginners and also, Ang et al. (1995) indicated that MRP implementation is new in Singapore.

5.9 MRP users profile

5.9.1 Previous experience

The respondents were asked to indicate their previous experience with automated complex information systems based on a 5-point Likert scale, with 1= very little and 5= very high (Q 30 of the questionnaire). Table 5.17 exhibits the responses of that question in terms of mean and standard deviation as it is illustrated below:

Table 5. 17 The previous experience with automated, technically complex information systems reported by MRP users of the total sample.

Item	Mean*	SD
The previous experience	2.92	.56

N= 51 * Based on a 5-point Likert scale, with 1= very little and 5= very high.

Our findings indicate that the MRP users in Egypt had received a moderate experience with automated complex information systems before implementing an MRP system. This result is consistent with our findings which suggest that 15.7% of MRP companies in Egypt did some in-house software development and 11.8% of MRP companies maintain their system in-house.

This result also concurs with the claim that operations/production managers responsible for the implementation of MRP systems in US companies have not had previous experience in the implementation of complex information systems (Burns et al., 1991). Both Kruskal Wallis Test and One Way of Variance (ANOVA) techniques showed no significant difference among MRP users concerning the issue under investigation (see Table 5.9.1 in Appendix B).

Furthermore, the MRP users in Egyptian manufacturing companies were asked to indicate their formal training associated with MRP implementation. Table 5.18 shows level of formal training that MRP users got.

Table 5. 18 The formal training associated with MRP implementation*.

Item	N	%
a) College graduate	42	82.4
b) Some college education	3	5.9
c) Technical school graduate	6	11.8
d) High school graduate	0	0.0
e) Less than high school	0	0.0
Total	51	100.0

* Q 30 of the questionnaire.

Table 5.18 reveals that about 82.4% of MRP users in Egypt were a college graduate against 44.0% of the Turnipseed et al, sample. (1992).

5.9.2 MRP users support

Table 5.19 shows that 88.5% of MRP users were at least supportive to the decision to implement an MRP system. This result to a large extent is similar to the findings of the Turnipseed et al. (1992) study which found that 90.0% of MRP users in the US were at least supportive for implementing MRP systems. This is a good sign as the level of users support has often been identified as one of major implementation prerequisites (Callarman and Heyl, 1986; Dilworth, 1993).

Table 5. 19 Level of support of MRP implementation by MRP users in different contexts*.

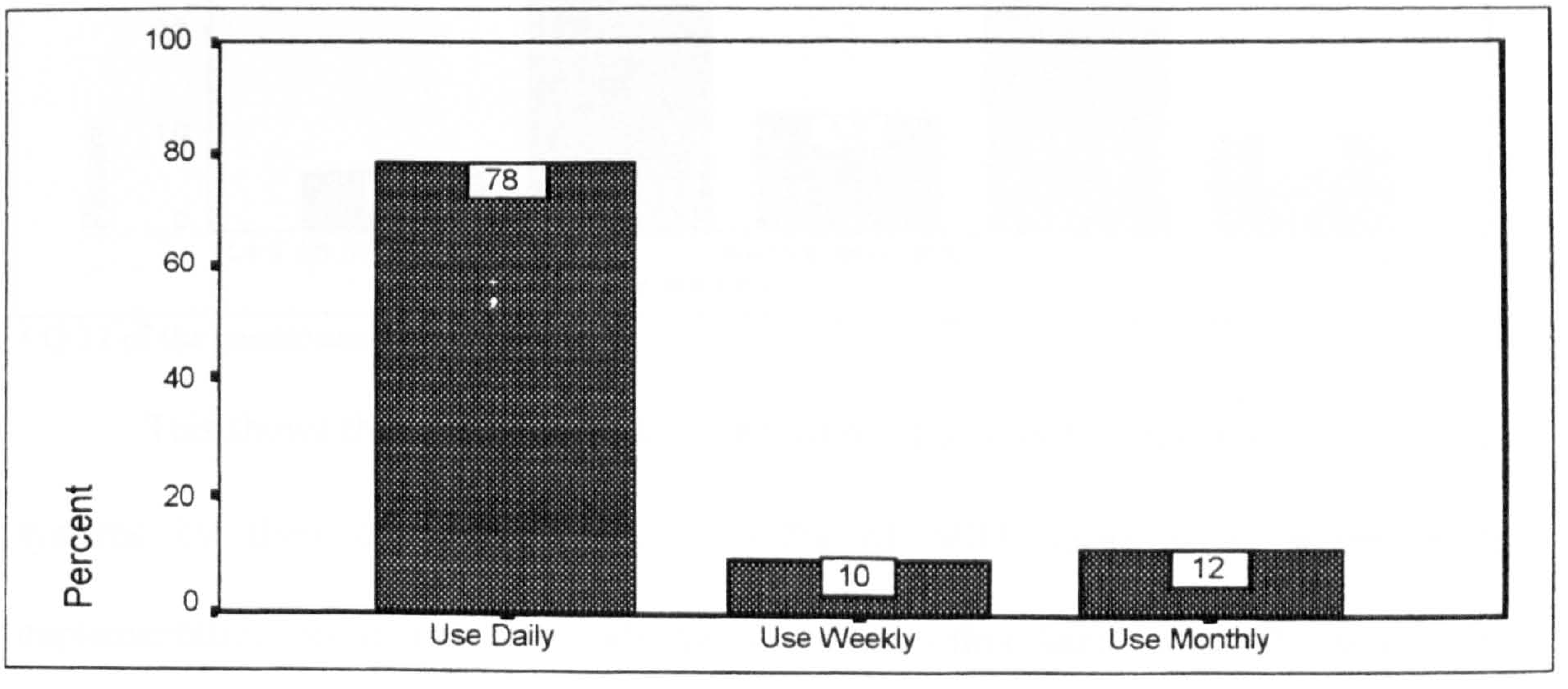
Item	Egypt		US	
	N	%	N	%
a) Total support	7	13.5	28	38.0
b) Very supportive	26	50.0	18	24.0
c) Supportive	13	25.0	19	27.0
d) Neutral	6	11.5	7	10.0
e) Opposed implementation	0	0.0	0	0.0
Total	52	100.0	72	100.0

* Q 32 of the questionnaire.

5.9.3 The degree of utilising the outputs of MRP systems

The MRP users were asked about the extent to which they utilised the outputs of MRP systems.

Figure 5. 5 The extent to which MRP users utilise the outputs of an MRP system*.



* Q 29 of the questionnaire.

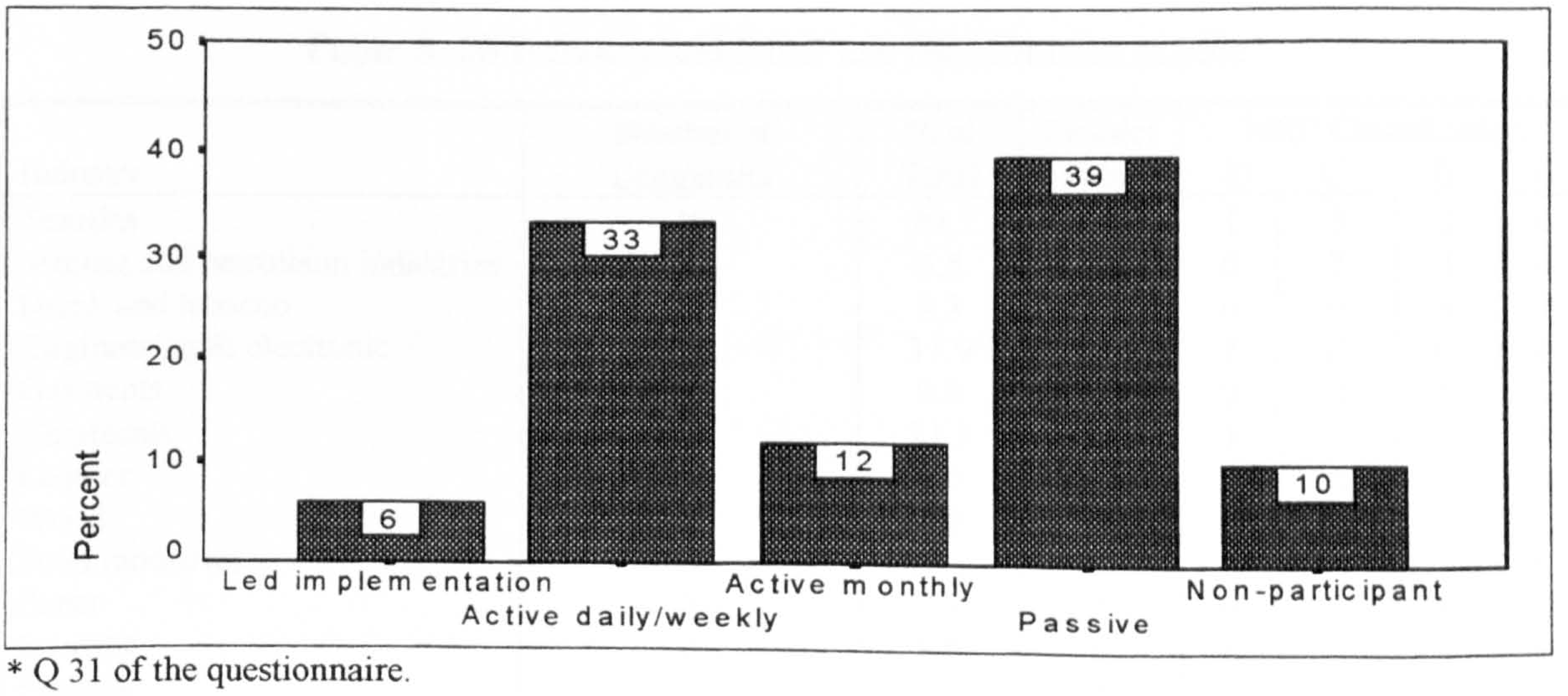
Figure 5.5 shows that the majority of MRP users in Egypt (78.0%) use the MRP system outputs on at least a daily basis. In the same direction, Turnipseed et al. (1992) found that 75.0% of MRP companies in the US used the MRP system outputs on at least a daily basis.

This result may help explain why a majority of MRP users in the two studies were at least supportive at implementing MRP systems.

5.9.4 User involvement

The respondents were asked to identify their involvement in the implementation of MRP systems as illustrated in Figure 5.6 below:

Figure 5. 6 People involvement in the implementation of MRP systems*.



* Q 31 of the questionnaire.

This shows that 39.0% of MRP users were passive in the implementation of MRP systems by their companies. About 33.3% of MRP users were active in the implementation on at least a weekly basis. On the other hand, only 10% were non - participant. By comparison, 10% of the Turnipseed et al, sample., (1992) led the MRP implementation, and about 40.0% were active with the implementation on at least a weekly basis.

Westbrook (1995) recommends that MRP companies, to achieve successful implementation of MRP systems, should involve users in the design of the system, to capture their commitment and to avoid their misunderstanding of the current procedures.

5.10 The stage of MRP implementation

The respondents were asked to assess their state of MRP implementation based on Class D-C-B-A system suggested by Wight (1984)[4], where Class D refers to the least advanced MRP, and Class A refers to the most advanced MRP system. Table 5.20 shows how the Egyptian users classified themselves.

Table 5. 20 Industry and MRP use classification profile*.

Industry	Number of Companies	% of Total	Reorder Point	MRP Classification			
				D	C	B	A
Textiles	19	20.7	11	1	5	2	0
Mining and petroleum industries	6	6.5	3	0	2	1	0
Drink and tobacco	3	3.3	3	0	0	0	0
Engineering & electronic	29	31.9	4	1	11	13	0
Garments	0	0.0	0	0	0	0	0
Chemicals	20	21.9	9	1	7	3	0
Leather	0	0.0	0	0	0	0	0
Wood	0	0.0	0	0	0	0	0
Food industries	10	10.9	6	1	0	3	0
Paper	3	3.3	3	0	0	0	0
Printing	0	0.0	0	0	0	0	0
Plastics	2	2.1	2	0	0	0	0
Total	92	100.0	41	4	25	22	0
	Percent of Total		44.6	4.3	27.2	23.9	0.0
	Percent Considering only MRP			7.8	49.0	43.2	0.0

* Q 25 of the questionnaire.

[4] It is interesting to remind the reader that term user class and the stage of MRP implementation are used interchangeably in this thesis, and this has been discussed in section 2.8.4.4 (Chapter. 2).

Based upon Table 5.20 several observations can be made:

a) 49.0% of MRP companies claimed to be Class C user which means that they use MRP system as an order launching system and to manage inventory, but they do not include the use of feedback for the readjustment of orders in response to actual performance. 43.2% of MRP companies reporting MRP usage identify themselves as Class B users, namely, they use MRP system as a Closed-loop MRP system for production operations control, for vendor follow-up system, and for detailed capacity requirements planning (Dilworth., 1993). This result is consistent to a great degree with Table 5.13 which suggests that about 58.0% of MRP users defined MRP system as a tool for planning and control for production only.

b) Table 5.20 indicates that no MRP companies in Egypt claimed to be Class A user. This result can be interpreted as follows:

- That manufacturing company needs to have longer experience with MRP implementation in order to be Class A user, while the Egyptian users are still relatively beginners. Our findings indicate that 73% of MRP companies had installed their systems for 3 to 10 years and which can be seen to be synchronised with the current stages of implementation. Voss (1986) has said that manufacturing companies need ten years to learn how to implement MRP systems.
- That Class A users have more sophisticated MRP modules such as RCCP and CRP modules, while our findings indicate that the Egyptian users had implemented the basic modules such as BOM and MPS modules.

- That Class A users have more integrated systems, while our findings indicate that the majority of MRP modules are not fully integrated so far.

c) Table 5.20 indicates that 82.8% of engineering & electronic industries are at stages B & C and had achieved the highest stage of MRP implementation among the Egyptian industries. This result is consistent with Cooper & Zmud's studies (1989; 1990) concerning MRP infusion within the US companies. The first study found that 12 out of 37 MRP users with Classes C & B are electronic companies, and in the second study, found that 14 out of 32 MRP users with Classes C & B are also electronic companies. The foregoing analysis provides strong evidence that MRP systems are more developed in the engineering & electronics industries than the other industries.

For comparative purposes, our findings are displayed alongside Cooper & Zmud (1989) and Laforge & Sturr (1986) findings concerning the stage of MRP implementation in the US companies, as it is illustrated in Table 5.21 below:

Table 5. 21 MRP Classification percentages of the sample firms in different contexts.

	Current Study		**Cooper & Zmud Study**		**Laforge & Sturr Study**	
User class	N	%	N	%	N	%
Class A	0	0.0	1	2.4	25	25.0
Class B	22	43.8	12	28.5	31	31.0
Class C	25	47.9	24	57.0	41	41.0
Class D	4	8.3	5	12.0	3	3.0
Total	51	100.0	42	100.0	100	100.0

Table 5.21 indicates that a majority of MRP companies classified themselves as either Class B or Class C MRP users in the three studies. Of the MRP companies in the current study, 91.7% classified their system as either Class B or C. By comparison, 85.5% of the Cooper & Zmud sample claimed to be Class B or Class C MRP users, in

contrast, 72.0% of MRP companies of the Laforge & Sturr sample reported themselves to be Class B or Class C MRP users. This result clarifies that MRP companies in Egypt and the US are to some extent similar in relation to the stage of MRP implementation.

5.11 Summary and conclusions

The main purpose of the this chapter has been to present and discuss the state of practice of MRP systems in Egyptian manufacturing companies, and to compare our results with the results of related previous studies in order to identify the similarities and dissimilarities in the nature of MRP implementation in Egypt compared to different contexts. Having discussed that, the following is a summary of findings:

(1) The results of the current study suggest that the implementation of MRP systems in Egypt is relatively similar to that in Singapore, as reported by Sum & Yang (1993), as a newly industrialising country; Anderson et al. (1982) and Laforge and Sturr (1986) in the US as a developed country.

(2) The survey findings suggested that MRP implementation is more likely to be in engineering and electronic industries and less likely to be in other industries whether in Egypt or Singapore or the US. The need for implementing MRP systems is likely to be greater when companies are larger, older, complex, and their marketing strategy is a combination of make to order and make to stock products in the three countries.

(3) The survey findings suggest that limited knowledge about MRP systems can be considered as the most important obstacle that impedes MRP implementation by the Egyptian and Singaporean users, while lack of MRP training, education and expertise

were identified as a critical problems encountered in the implementation process either in Egypt or Singapore.

(4) In contrast, the interesting differences that emerged can be summarised as follows: a) the current study reveals that the most MRP companies in Egypt are state owned. In contrast the majority of MRP companies in Singapore and in the US are multinational owned, and this reflects that the public sector still dominates industry in Egypt, b) from the empirical evidence, the study indicates that the organisational arrangements for implementing MRP systems incline to be more formal for the US users than their peers in Egypt and Singapore, c) our study reveals that top management support in Egypt has a great impact on the extent and rate of the acceptance of MRP systems more than their peers in Singapore and the US. The reason behind that may be that the MRP companies in Egypt are still in an early implementation stage (57.0% of companies under investigation had implemented MRP systems for 5 or less than 5 years) so top management are highly involved in MRP implementation, and d) in addition, the findings indicated that software/hardware vendors play a vital role in the implementation of MRP systems. In contrast, their role in US companies is less. The reason for this may be that US users had more expertise in the implementation of MRP systems than the Egyptian users.

(5) In general terms, the study reveals that the current usage of MRP systems is not very widespread in Egypt. Despite the Egyptian government support (e.g., grants, incentives) in promoting use of MRP systems, 52 of 93 companies participated in the empirical analysis. had implemented MRP systems and 41 had not yet implemented.

In summary, in this chapter an attempt was made to investigate the state of MRP practices in Egyptian manufacturing companies.

In order to investigate the extent to which MRP implementation is effective by the Egyptian users, the next chapter (i.e. Chap. 6) is intended to assess the effectiveness of MRP practices measured by the benefits obtained from MRP implementation by MRP users in Egypt.

CHAPTER SIX

Data Analysis

MRP Implementation Benefits

6.1 Introduction

The purpose of this chapter is three fold, first to assess empirically the effectiveness of MRP practices measured by the benefits obtained from MRP implementation in Egyptian manufacturing companies, second to report the costs of MRP installation by the Egyptian users, and third to test hypothesis relating to the benefits obtained from MRP implementation. It was suggested earlier in Hypothesis # (1) that "Not all MRP users in Egyptian industrial sector attain the same benefits from MRP implementation" (see Chapter 4 section 4.3.3).

To achieve these objectives, the data collected in the survey of fifty-two MRP companies concerning the benefits obtained from MRP implementation and the costs spent on MRP installation by Egyptian manufacturing companies are presented and discussed in three main sections, as follows.

Section 6.2 presents a preliminary analysis of the benefits obtained from MRP implementation by the Egyptian manufacturing companies. This is divided into two subsections.

The first presents the objective benefits obtained from MRP implementation by the Egyptian manufacturing companies. This is done by investigating the objective benefits obtained from MRP implementation from the point of view of MRP users. Statistical analysis of the data collected from MRP companies was used in two cases.

The first case is analysis of the data collected in terms of means and standard deviations and which covers the objective benefits obtained from MRP implementation by MRP companies. Then an attempt is made to determine the extent of the improvements achieved from MRP implementation for each of the Egyptian manufacturing industries, and to find out if significant differences exist between individual industries using Kruskal Wallis Test (K-W) and One Way of Variance (ANOVA) (to test hypothesis # 1).

The second case is analysis of how much progress towards the final target has been made for each of the five performance measures (i.e. inventory turnover, delivery lead time, percent of time meeting delivery promises, percent of orders requiring "splits" because of unavailable material, and number of expediters[1]) of MRP implementation of the total sample. This subsection concludes by presenting how this is different from previous studies through comparing the result of this study and those obtained by previous studies. In this case, the Paired T-Test technique was employed to find out if significant differences exist between the current study findings and the findings of each of the previous studies.

The second subsection of section 6.2 presents the subjective benefits obtained from MRP implementation by the Egyptian manufacturing companies. These are investigated from the point of view of MRP users. Means and standard deviations of responses about the subjective benefits obtained from MRP implementation of the total sample were calculated and the Kruskal Wallis Test (K-W) and One Way of Variance

[1] Because some companies cannot meet delivery dates, a number of expediters have been used (i.e. a number of people who are appointed) to help companies make two days (i.e. due date and need date) have been coincided.

(ANOVA) techniques were used to find out if significant differences exist amongst MRP users perceptions, concerning the degree of improvement on all subjective benefit measures of MRP implementation (again testing hypothesis # 1), and finding out the extent of the perceived subjective benefits versus reasons for implementing MRP systems. The result is then reported of using a Paired T-Test technique to find out if significant differences exist between the current study findings versus the findings of each of the previous studies.

Section 6.3 deals with the costs spent on MRP implementation by Egyptian manufacturing companies. It reports what has happened in the Egyptian manufacturing companies concerning the costs of MRP installation and the expected substantial additional investment over the next three years.

Statistical analysis of the data collected from MRP companies were used in two cases. The first is analysis of the results of the two questions relating to MRP installation costs and the expected substantial additional investment over the next three years in terms of means and standard deviations. The second is analysis of the strength of the relationship between company size and MRP installation costs using Spearman's Correlation Coefficient. These results are compared with those obtained from previous studies.

Section 6.4 is intended to summarise the research findings regarding the benefits obtained from MRP implementation and its installation costs from points of view MRP users within the Egyptian manufacturing companies.

6.2 MRP implementation benefits

As it was stated in the literature survey (see section 2.7 in Chapter Two) that the effectiveness of MRP practices is measured by the benefits obtained from MRP implementation. Previous studies concerning MRP implementation benefits can be sorted into two types: the first provides only a listing of the benefits of MRP implementation success such as Sum and Yang (1993); Ang et al. (1995) and Sum et al. (1995), and the second attempts to develop or validate a standard measure concerning the expected potential benefits of MRP implementation (Duchessi et al., 1988). There are fewer studies of this second type.

With this in mind, the present study attempts to support the latter type. To do this, the effectiveness of MRP implementation is measured by (1) tangible benefits or improved performance measures, and (2) subjective benefits or user satisfaction as in (White et al., 1982; Anderson and Schroeder, 1984; Duchessi et al., 1988).

Accordingly, the respondents were asked to outline the benefits obtained from MRP implementation and which were measured in two ways in the research survey, firstly by improvements in the objective benefit measures and secondly by the subjective ratings of benefits.

This section is intended to determine the degree to which the Egyptian manufacturing companies achieved the expected potential benefits of MRP implementation. The field study findings on this one issue are discussed below:

6.2.1 The objective benefits obtained from MRP implementation

Anderson and Schroeder (1984) collected five objective performance estimates (i.e. inventory turnover, delivery lead time, percent of time meeting delivery promises, percent of orders requiring "splits" because of unavailable material, and number of expediters) and those were used to judge the extent that manufacturing companies achieved improvements in performance as a result of MRP implementation.

It is worth mentioning here that the literature review reveals that there are some difficulties in obtaining measures for tangible benefits such as the respondents do not keep track of the required data for performance measures over time (White et al., 1982; Sum and Yang, 1993; Sum et al., 1995). Surprisingly, most of the respondents in this study gave the required data for using performance measures.

To determine to what extent the Egyptian manufacturing companies are reaping tangible benefits of MRP implementation, the findings in this sub-section are divided into five headings:

- The objective benefits obtained from MRP implementation of the total sample.
- The extent of the improvements achieved from MRP implementation in the individual industries scored by MRP users.
- The variation between industries for each of the five MRP performance measures (i.e. the tangible benefits achieved) (testing hypothesis # 1).
- The progress achieved in MRP implementation for each of the five MRP performance measures of the total sample.

- The comparison with previous studies relating to the tangible benefits obtained from MRP implementation.

The field study findings on these five aspects are discussed in detail below:

6.2.1.1 The objective benefits obtained from MRP implementation of the total sample

The five tangible performance measures used were inventory turnover (sales/inventory ratio), delivery lead time (days), percent of time meeting delivery promises (%), percent of orders requiring "splits" because of unavailable material (%), and number of expediters (number of people). These manufacturing performance measures were chosen based on the kinds of measures typically used by manufacturing companies to reflect performance as in (Schroeder et al., 1981; White et al., 1982; Anderson et al., 1982, Anderson and Schroeder, 1984; Laforge and Sturr, 1986).

The MRP users were asked to estimate (1) levels of performance on the five measures prior to the implementation of an MRP system, (2) current levels of those performance measures, and finally, (3) what these performance measures will be in the future when their companies complete the development of their MRP systems implementation. There were thus fifteen individual responses for each company.

Table 6.1 exhibits the findings of performance on the five measures examined within this study based on MRP user's experiences and also the current improvement in each performance measure of the total sample using Equation 6.1.

$$\text{Current improvement} = [(\text{Current estimate} - \text{Pre estimate}) / (\text{Pre estimate})] \quad \textbf{(6.1)}$$

Table 6. 1 MRP performance measures reported by MRP users of the total sample (average value* and standard deviation below in parenthesis)***.

Performance Measures	Pre-MRP Estimate	Current Estimate	Future Estimate	Current improvement**
a) Inventory turnover (ratio)	2.8	3.9	6.1	39.3%
	(1.1)	(.90)	(.76)	
b) Delivery lead time (days)	71.3	53.5	39.9	25.0%
	(11.1)	(10.4)	(8.0)	
c) Percent of time meeting delivery promises (%)	56.3	80.1	91.2	42.3%
	(6.7)	(10.4)	(5.0)	
d) Percent of orders requiring "splits" because of unavailable material (%)	33.7	17.4	7.5	48.4%
	(8.0)	(6.1)	(3.0)	
e) Number of expediters (number of people)	12.8	6.7	6.6	47.7%
	(2.1)	(2.0)	(1.4)	

*N=52 ** Using Equation 6.1 *** Q 33 of the questionnaire.

.............Based on Table 6.1 three observations can be made as follows:

a) The increase of percent of time meeting delivery promises, the reduction of the percent of split orders and the average number of expediters had achieved the highest level of improvements of MRP implementation in proportions to (42.3%), (48.4%) and (47.7%) successively.

b) In contrast, both delivery lead time and inventory turnover had received the lowest level of improvement of MRP implementation by Egyptian manufacturing companies in proportions to (25%) and (39.3%) respectively.

c) The analysis indicates that MRP companies reported substantial improvement in all five performance measures and this provides strong evidence that MRP companies under investigation are experiencing the improvement expected by the mean performance measures.

6.2.1.2 The extent of the improvements achieved from MRP implementation in the individual industries

This sub-section is intended to find out the extent of the improvements of tangible benefits achieved by each of the five manufacturing industries scored by MRP users. To do that, firstly Table 6.2 presents levels of MRP performance measures on average reported by Egyptian manufacturing industries using Equation 6.2.

$$\text{Average} = \frac{\sum \text{Level of performance measure}}{N} \qquad \textbf{(6.2)}$$

Where $\sum$ level of performance measure is the total of respondents for each level of MRP performance measures for each industry. N number of respondents from each industry.

Table 6. 2 Levels of MRP performance measures on average reported by industrial sector scored by MRP users.

Item		E	T	C	F	P
a) Inventory turnover	Pre-MRP	2.4	3.0	3.2	3.5	3.3
	Current-MRP	3.5	4.4	4.1	4.5	4.3
	Future-MRP	5.9	6.5	6.2	6.0	6.3
b) Delivery lead time (days)	Pre-MRP	65.9	77.6	76.5	76.0	76.0
	Current-MRP	50.7	56.4	57.0	39.8	62.3
	Future-MRP	37.0	44.5	42.1	40.0	44.3
c) Percent of time meeting delivery promises (%)	Pre-MRP	55.2	58.0	58.0	56.0	56.0
	Current-MRP	76.7	80.5	82.6	90.0	88.7
	Future-MRP	90.2	91.0	92.9	92.0	92.7
d) Percent of orders requiring "splits" because of unavailable material (%)	Pre-MRP	29.8	41.8	36.1	36.0	34.3
	Current-MRP	17.1	16.0	18.5	19.0	17.0
	Future-MRP	6.7	8.4	7.8	7.8	9.7
e) Number of expediters (number of people)	Pre-MRP	10.1	12.9	14.4	13.8	13.7
	Current-MRP	5.2	7.5	7.9	7.0	8.3
	Future-MRP	1.5	1.0	1.9	2.0	2.3

E= Electronic and engineering industry T= Textile industry C= Chemical industry
F= Food industry P= Petroleum industry

Secondly, Table 6.3 states the degree of improvements achieved from MRP implementation by the Egyptian industrial sectors.

Table 6. 3 The extent of improvements achieved by industrial sectors scored by MRP users *(%).

Item	E	T	C	F	P
a) Inventory turnover	45.8	**46.7**	28.1	28.6	30.3
b) Delivery lead time (days)	23.1	27.3	25.5	**47.6**	18.0
c) Percent of time meeting delivery promises (%)	38.9	38.8	42.4	**60.7**	58.4
d) Percent of orders requiring "splits" because of unavailable material (%)	42.6	**61.7**	48.8	47.2	50.4
e) Number of expediters (number of people)	48.5	41.9	45.1	**49.3**	39.4

* Using Equation 6.1

Surprisingly, it appears from Table 6.3 that food industry had achieved the highest degree of improvements concerning the reduction of delivery lead time and number of expediters and also increasing the percent of time meeting delivery promises. On the other hand, the textile industry had achieved the highest degree of improvements of inventory turnover and the reduction of the percent of split orders. This result is very interesting, because it provides strong evidence that the benefits obtained from MRP implementation are not restricted mainly to the electronic and engineering industry. Mady (1992) and Dilworth (1993), have argued that MRP systems are more likely to be in manufacturing companies with dependent demand between products such as electronic industry, but our study shows that benefits can be attained by other manufacturing industry sectors such as the textile and food industries in which the demand for components and parts are dependent and independent.

Furthermore, calculating the averages[2] of the improvements of the five performance benefits obtained from MRP implementation by the Egyptian industrial sectors were 31.%, 43.3%, 38.0%, 50.3% and 39.3% for the engineering, textile,

2. Average = $\frac{\sum \text{Improvements}}{N}$, where $\sum$ improvements is the total of improvements in each industry for the five performance measure. N number of performance measures.

chemical, food and petroleum industries respectively. This indicates that the electronics and engineering industry had achieved the lowest average for all the five tangible measures. In contrast, the results indicate that the food industry had achieved the highest average. But a word of caution must be made, with regard to the interpretation of these results. The food industry more than the others because it represents 8% of the total sample while the electronics and engineering industry represent 50% of the total sample.

6.2.1.3 The variation between industries concerning MRP performance measures scored by MRP users

It appears from Table 6.2 that there are real differences exist between individual industries with respect to MRP performance measures scored by MRP users. Using Kruskal Wallis and One Way Analysis of Variance (ANOVA) to find out if these differences are statistically significant or not, show the following findings:

a) Pre-MRP estimate: both techniques showed statistically significant differences exist between industries in two tangible measures-"the percent of split orders" and " number of expediters" because the calculated ***Ps*** (i.e. calculated values based upon statistical technique used) were less than the accepted significance level **(.05)** whether using Kruskal Wallis or One Way Analysis of Variance (ANOVA), (see Table 6.2.1 in Appendix C). An examination of Table 6.2 (sub-section 6.2.1.2), reveals that there is a difference between the textile industry on one hand and the rest of the industries on the other hand concerning "the percent of split orders" whereas it has achieved the highest percent of split orders because of unavailable material prior to MRP implementation, this result can be interpreted in light of the fact that the Egyptian textile sector was importing most textile products such as raw cotton, raw silk, nylon, threads, and polyester from various foreign suppliers in the last two decades, which has led to increasing the percent of orders requiring "splits" because of unavailable materials.

On the other hand, there is a difference in "number of expediters" between the chemical industry on one hand and the rest of the industries on the other, whereby it had the highest number of expediters prior to the implementation of MRP. This difference may be due the chemical industry processes being subject to product customisation while the other industries processes are highly standardised.

b) Current- MRP estimate: both techniques showed statistically significant differences amongst the five industries in one tangible measure " number of expediters" because the calculated *Ps* were less than the accepted significance level **(.05)**, whether using Kruskal Wallis or One Way Analysis of Variance (ANOVA) (see Table 6.2.1 in Appendix C). An examination of Table 6.2 (sub-section 6.2.1.2), reveals that there is a difference in means for "number of expediters" between the petroleum refinery industry on one hand and the rest of the industries on the other hand, whereby it returns the highest number of expediters which may be due to having faced many difficulties in coinciding due date and need date for the required orders.

On the other hand, the results in Table 6.2.1 (Appendix C), indicate that there is no significant difference amongst the five industries concerning the percent of split orders. This means that the implementation of MRP systems led to a significantly greater reduction of the percent of split orders for the production needs in the textile industry.

c) Future- MRP estimate, both techniques showed no statistically significant differences amongst the five industries concerning the expected progress of each of the five objective measures of MRP implementation.

In the aggregate, the results mentioned above partly support the suggested hypothesis, which is that not all MRP users in Egyptian industrial sector attain the same benefits from MRP implementation.

6.2.1.4 The progress achieved from MRP implementation for each of the five performance measures of the total sample

This sub-section is devoted to the level of progress for each of the five performance measures by taking account of users estimates of future-MRP performance. The degree of progress in each performance measures was computed as in White et al. (1982), who provided a measure of progress which can be used in each area of manufacturing performance. They constructed a measure of progress towards expected performance which measured each company's current progress against its own expected future performance using Equation 6. 3.

$$\text{Progress} = \frac{CurrentEstimate - \text{"}\Pr e - MRP\text{"}\,Estimate}{FutureEstimate - \text{"}\Pr e - MRP\text{"}\,Estimate} \qquad \textbf{(6.3)}$$

Table 6.4 illustrates progress for each of the five performance measures for all MRP companies from points of view of MRP users.

Table 6. 4 The achieved improvement versus the expected progress for each of the five performance measures for all MRP companies.

Item	The achieved improvement (%)*	Progress (%)**
a) Inventory turnover (ratio)	39.3	33.3
b) Delivery lead time (days)	25.0	56.7
c) Percent of time meeting delivery promises (%)	42.3	68.2
d) Percent of split orders (%)	48.4	62.2
e) Number of expediters (number of people)	47.7	54.5

* Using Equation 6.1 ** Using Equation 6.3

Taking account of the future MRP estimate, it appears from Table 6.4 that:

a) the MRP users feel that more improvement can be achieved in the future when their MRP systems are fully installed.

b) MRP users feel that most improvement is yet to be made in increasing inventory turnover (39.3% made so far). This may be due to a reduction of delivery lead time and an increase of time meeting delivery promises obtained from MRP implementation. On the other hand they expect a lower progress in inventory turnover because most of the electronic and engineering companies (50% of the total sample), have big inventories of components and parts as a result of their implementation of the agreements with foreign suppliers. At the same time, they are facing strong competition from foreign competitors which may result in a decrease of their sales, and in turn decreasing their inventory turnover (sales/inventory).

6.2.1.5 Comparison with the previous studies

As far as researcher is aware, there are no publications concerning the benefits of MRP systems implementation in less developed countries. However, it is of interest to compare our findings with studies of MRP implementation in developed countries. Our findings can be compared with two previous studies concerning the tangible benefits of MRP practices in USA (Anderson et al., 1982; Laforge and Sturr, 1986).

To do this, the findings in the two previous studies are displayed alongside our responses. Table 6.5 shows the comparison of the tangible benefits of MRP systems implementation between the current study and the two previous studies.

Table 6. 5 The comparison of the tangible benefits of MRP systems implementation in different contexts (standard deviation* below in parenthesis).

Item		Pre-MRP Estimate	Current Estimate	Future Estimate	The Achieved Improvement[a]	Progress[b]
a) Inventory turnover	Current	2.8 (1.1)	3.9 (.90)	6.1 (.76)	39.3	33.3
	Anderson	3.2 (2.4)	4.3 (3.1)	5.3 (3.8)	34.4	52.4
	Laforge	4.5 (4.3)	7.9 (6.5)	11.2 (7.3)	75.6	50.7
b) Delivery lead time (days)	Current	71.3 (11.1)	53.5 (10.4)	39.9 (8.0)	25.0	56.7
	Anderson	71.4 (65.8)	58.9 (59.6)	44.5 (43.3)	17.5	46.7
	Laforge	55.6 (31.2)	41.7 (23.6)	31.8 (20.5)	25.0	58.4
c) Percent of time meeting delivery promises (%)	Current	56.3 (6.7)	80.1 (10.4)	91.2 (5.0)	42.3	68.2
	Anderson	61.4 (21.4)	76.6 (18.2)	88.7 (13.8)	24.8	55.7
	Laforge	73.9 (17.8)	88.6 (7.1)	94.6 (5.9)	19.9	71.0
d) Percent of orders requiring "splits" because of unavailable material (%)	Current	33.7 (8.0)	17.4 (6.1)	7.5 (3.0)	48.4	62.2
	Anderson	32.4 (22.0)	19.4 (17.3)	9.1 (8.8)	40.1	55.8
	Laforge	29.0 (27.4)	13.5 (15.0)	5.5 (5.6)	53.4	65.9
e) Number of expediters (number of people)	Current	12.8 (2.1)	6.7 (2.0)	1.6 (1.4)	47.7	54.5
	Anderson	10.1 (16.0)	6.5 (9.2)	4.6 (6.0)	35.6	65.5
	Laforge	10.8 (20.7)	5.1 (9.7)	2.1 (2.0)	52.8	65.5

*The standard deviations are used in order to state the degree of consistency in improved performance.
[a] Using Equation 6.1 [b] Using Equation 6.3

Based on Table 6.5 there are several observations that can be made.

a) It appears from the pre-MRP estimate column that firms in this study performed worse, compared to the US firms, on all but one performance measure (only delivery lead time being longer in two US studies which is dependent on the firms in the survey), but with the exception of inventory turnover, the results are relatively similar in Egypt and the US.

b) But after MRP implementation firms in the current study had achieved a greater improvements on all five performance measures than the firms in Anderson's study. On the other hand, the results of current study are similar to those of Laforge concerning the degree of improvement in meeting delivery lead times; are better than the Laforge study regarding the degree of improvement in meeting delivery promises; but are worse than the Laforge study concerning the rest of the five performance measures.

c) The progress made on the five performance measures by the Egyptian firms is worse than their peers in the Laforge study, but is better than those in the Anderson study on these measures- that of their delivery lead time, meeting delivery promises and percent of split orders.

d) In contrast with previous studies showing that MRP users are dissatisfied with its implementation such as Aggarwal (1985); Fintech (1989); Sandeep (1992); Hill (1993); Browne et al. (1996) and Carrie et al. (1997), the results of the three studies, as a group, strongly provide further evidence that MRP companies experience significant improvements in manufacturing performance of MRP implementation.

e) With the exception of the standard deviations for inventory turnover measure in the other two studies and percent of time meeting delivery promises measure in the current study, the research findings indicate that the standard deviations are inclined to decrease as one moves from pre-MRP estimate to the current estimate to the future estimate which may indicate that there is a confluence of the MRP companies under investigation toward this improved performance. The standard deviations are used in order to state the degree of consistency in improved performance.

To find out if the differences mentioned above between the current study and each one of the previous two studies are statistically significant or not, the Paired T-Test technique was used to reveal that there is no significant differences amongst the three studies concerning the tangible benefits achieved from MRP implementation by manufacturing companies in Egypt and their peers in the US (see Table 6.2.2 in Appendix C).

6.2.2 The subjective benefits attained from MRP implementation

This section has highlighted the subjective benefits of MRP implementation which has been discerned by manufacturing companies surveyed. MRP users were asked to give their attitudes and intentions toward the subjective benefits obtained from MRP implementation, which means that intended use rather than actual use is often selected as a good measure of MRP implementation success because of many difficulties of actual use as in all previous studies, such as White et al. (1982); Sum and Yang (1993) and Sum et al. (1995).

Taking account of the above, a word of caution should be considered here because two main problems that may arise from using benefits which are self reported, the first, benefits can be overestimated due to the halo effect of MRP, and the second, benefits can be underestimated due to estimation errors (Schroeder et al., 1981). However, we have tried to reduce these problems to some extent through getting these estimates from MRP users who have involved in MRP implementation (i.e. production managers, inventory managers, materials managers, master schedulers and management information systems managers) as a relevant source for the required data as used in previous studies such as Sum and Yang (1993); Ang et al. (1995) and Sum et al. (1995).

This section of the research is intended to explore to what extent MRP users had perceived the subjective benefits of MRP implementation in the Egyptian manufacturing companies.

To do this, the issues under investigation are presented as follows:

- The subjective benefits perceived by MRP users.
- The variation among MRP users concerning the subjective benefits perceived (testing hypothesis #1).
- The degree of improvements on all subjective benefit measures of MRP implementation from points of view of MRP users.
- The extent of the subjective benefits perceived versus reasons for implementing MRP systems.
- The comparison with previous studies relating to the subjective benefits obtained from MRP implementation.

Below are the survey findings relating to these issues.

6.2.2.1 The subjective benefits perceived by MRP users

The subjective benefits of MRP implementation were measured by asking users their perceptions about a) improved competitive position, b) reduced inventory costs, c) increased throughput, d) improved product quality, e) improved productivity, f) better ability to meet volume/ product change, g) better production scheduling, h) reduced safety stocks, i) better cost estimation, j) co-ordination with marketing and finance, k) improvements in their ability to perform in their job, l) reduced informal systems for materials management/ inventory/ production control, m) increased BOM accuracy, and n) increased information on which to base decisions since MRP has been implemented (see section 2.7 in Chapter Two). Each respondent answered on a four -point scale ranging from little benefits to very much benefits.

A measure of user satisfaction was obtained by calculating the average of user perceptions of the success of MRP implementation. Table 6.6 summarises the subjective benefits obtained from MRP implementation of the total sample rated by MRP users in the Egyptian manufacturing companies. A higher rating indicates high subjective benefit obtained and a lower rating indicates low subjective benefit achieved.

Table 6. 6 The subjective benefits obtained from MRP implementation reported by MRP users of the total sample*.

Item	Mean**	SD
Reduced inventory costs	3.63***	.82
Better production scheduling	3.62	.66
Increased BOM accuracy	3.31	.96
Increased throughput	3.23	.67
Better cost estimation	2.85	1.06
Improved co-ordination with marketing and finance	2.75	.74
Reduced informal systems for materials management/inventory/production control	2.58	.89
Reduced safety stocks		
Improved productivity	2.40	72
Better ability to meet volume/product change	2.37	.63
Improved product quality	2.19	.84
Improved your ability to perform in your job	2.15	.36
Improved competitive position	1.92	.27
Increased information on which to base decisions since MRP has been implemented	1.83	.38
	1.81	.40

* Q 33 of the questionnaire,

** Based upon a four- point scale, score "1" for little benefit, "4" for very much benefit. (N=52)

*** The higher the mean, the greater the user satisfaction of item.

Based on Table 6.6 a number of observations can be made as follows:

a) It appears from Table 6.6, that reduced inventory costs received the highest rating by MRP users. This supports the claim that a common phrase in most manufacturing companies in Egypt is "We have got too much inventory" and we are ready to implement any technique to help us to overcome this problem.

b) It becomes clear that improved competitive position was a less commonly recognised outcome of implementing an MRP system, receiving the next to lowest rating's by MRP users. This means improved competitive position was not one of the major reasons for MRP implementation by the Egyptian manufacturing companies.

c) It is very clear that standard deviation of better cost estimation measure is the highest one which means that there is a big deviation among companies concerning this measure.

6.2.2.2 The variation among MRP users concerning the subjective benefits perceived

To find out if the differences amongst MRP users concerning their perception of the intangible benefits obtained from MRP implementation are statistically significant or not, the Kruskal Wallis and One Way Analysis of Variance (ANOVA) were performed. Both techniques showed a significant difference amongst MRP companies in three subjective benefit measures "improved product quality", "better ability to meet volume/ product change" and "improved ability to perform a job" respectively (see Table 6.2.3 in appendix C). Calculated ***Ps*** are less than the accepted significance level **(.05)**. An examination of Table 6.2.4 in (Appendix C) shows differences in means for the three measures as explained below:

a) There is a difference in means between production and inventory control managers on one hand and the rest of the MRP users on the other. Whereas both of them had received the lowest level of satisfaction compared with the others users concerning improving product quality.

b) Table 6.2.4 indicates that master scheduler users were more satisfied than the others regarding achieving better ability to meet volume/ product change. Perhaps because its their biggest concern i.e. a problem which is theirs to solve.

c) The findings in Table 6.2.4 show that inventory control managers had perceived the lowest degree of satisfaction with MRP implementation concerning improving their ability to perform in their job.

In the aggregate, the results mentioned above partly support hypothesis # 1.

6.2.2.3 The degree of improvements on all subjective benefit measures of MRP implementation from points of view of MRP users

For calculating the degree of improvement aims all subjective benefit measures of MRP implementation, two steps were performed as illustrated below:

(1) A measure of user satisfaction for the whole 14 subjective benefit measures was calculated using Equation 6.4.

$$SAT_n = \Sigma SAT / N \qquad (6.4)$$

Where, SAT_n is the average of user satisfaction for the whole 14 subjective benefits measures. SAT is user satisfaction for each subjective benefit measure. N number of respondents (N=52).

(2) Then, we located the value obtained from Equation 6.4 on the scale range for the whole subjective benefit measures. The satisfaction for all subjective benefit measures was ranged from 14 "lowest score" to 56 "highest score" (i.e. score 14 means that MRP company with score 1 "little benefit" for all the fourteen subjective benefits and on the other hand score 56 means that MRP company with score 4 "very much benefit" for all the fourteen subjective benefits).

Using the above mentioned, the users satisfaction for the whole 14 subjective benefit measures of MRP implementation was 36.64 score and which indicates that user satisfaction is approximately 65% for the whole 14 subjective benefit measures of the total sample.

All in all, the above result provides some indication of the degree of satisfaction with MRP implementation in the Egyptian manufacturing companies. Again, this result does not concur with past literature which indicates that over 60% of MRP users are not satisfied with the benefits obtained from MRP implementation (Fintech, 1989; Sandeep, 1992; Hill, 1993).

6.2.2.4 The extent of the subjective benefit perceived versus reasons for implementing MRP systems by manufacturing companies

This sub-section is intended to find out the extent of the subjective benefits perceived versus reasons for implementing MRP systems. This analysis may help manufacturing companies to know if are they on the right track in considering MRP implementation or not. Therefore, we have presented the major subjective benefits perceived versus reasons for implementing an MRP system as shown in Table 6.7 below.

Table 6. 7 The major benefits attained versus reasons for implementing an MRP system.

Major Benefits	Mean Score	Major Reasons	Mean Score
Reduced inventory costs	3.63	Lower inventory cost	4.69
Better production scheduling	3.62	Meet delivery dates better	4.63
Increased BOM accuracy	3.31	Inventory control	4.10
Increased throughput	3.23	Increase throughput	3.39
Better cost estimation	2.85	Production control	2.88
Improved co-ordination with marketing and finance	2.75	Improve productivity	2.62
Reduced informal systems for materials management/inventory/production control	2.58	Improve competitive position	2.61
		Improve quality of products	2.53
Reduced safety stocks	2.40		
Improved productivity	2.37		
Better ability to meet volume/product changes	2.19		
Improved product quality	2.15		
Improved your ability to perform in your job	1.92		
Improved competitive position	1.83		
Increased information on which to base decisions since MRP has been implemented	1.81		

Based on Table 6.7 three observations can be made as follows:

a) It appears from the Table 6.7, that "lower inventory cost" is the important reason for implementing MRP systems, and at the same time is the most important subjective benefit obtained from MRP implementation.

b) In general terms we can say that most of the benefits obtained from MRP implementation match the implementation reasons except for improved competitive position measure. Only a few companies reported some significant satisfaction about improvement on this measure.

c) It appears from Table 6.7 that MRP companies in the Egyptian industrial sector are intending to use MRP system as a tool for achieving manufacturing efficiency measured by reduced inventory costs, better production scheduling, increased BOM accuracy, etc. rather than as a means for improved their competitive position. These findings are similar to those reported in Sum & Yang (1993).

6.2.2.5 Comparing the present research findings with the previous studies

This sub-section compares the findings of the current study with those of previous studies concerning the subjective benefits achieved by MRP implementation.

For comparative purposes, the findings of two previous studies, one of them concerning the subjective benefits achieved for MRP practices in Singapore (Sum & Yang, 1993) and the other relating to the subjective benefits obtained from MRP practices in US (Schroeder et al., 1981), are displayed alongside our responses. Table 6.8 illustrates that MRP users in Egyptian manufacturing companies believe that the expected subjective benefits from MRP implementation have been attained.

Table 6. 8 The comparison of the subjective benefits of MRP systems implementation in different contexts. (mean value*).

Item	Current Study	Sum and Yang study	Schroeder Study
Reduced inventory costs	3.63	3.65	N/A**
Better production scheduling	3.62	3.87	2.7
Increased BOM accuracy	3.31	N/A	N/A
Increased throughput	3.23	3.48	N/A
Better cost estimation	2.85	3.69	2.2
Improved co-ordination with marketing and finance	2.75	N/A	2.4
Reduced informal systems for materials management/inventory/production control	2.58	N/A	N/A
Reduced safety stocks	2.40	3.46	2.4
Improved productivity	2.37	3.66	N/A
Better ability to meet volume/product changes	2.19	3.83	N/A
Improved product quality	2.15	N/A	N/A
Improved your ability to perform in your job	1.92	N/A	N/A
Improved competitive position	1.83	3.40	2.1
Increased information on which to base decisions since MRP has been implemented	1.81	N/A	N/A

* The comparison was built on the mean score for each subjective benefit measure in the three studies.
** N/A, means response is not available because option was not reported in the other two studies.

The analysis of Table 6.8 provides us with the following observations:

a) To a large extent, our findings are similar to Sum & Yang findings (1993). This is true specially with regard to reduction of inventory costs. This result concurs with the findings of Anonymous (1996), who reported that the biggest benefit obtained from MRP II implementation, by the company James Coney, was lower costs for holding stocks of obsolete inventory.

b) MRP companies in the current study, Sum & Yang study, and the Schroeder study are achieving operational benefits more than a strategic benefits. This result is contrary to that of Leng (1987); White and Wharton (1990); Lummus and Wilson (1992) and Strzelczak (1995), who argue that manufacturing companies may adopt new production management systems such as MRP and JIT, as a response to regional and international competition pressures.

To find out if significant differences exist between the current study and each one of the previous two studies, the Paired T-Test technique was used. This reveals that there is significant difference between Sum and Yang study and the current study and Schroeder et al. study. An examination the results in Table 6.2.5 (see Appendix C), indicate that MRP users in Singaporean companies had perceived the higher degree of satisfaction with MRP implementation than their peers in Egypt and US. In contrast, there is no significant difference between the current study and Schroeder et al. study, which means that MRP users in the Egyptian and the US companies had not perceived dissimilar degrees of satisfaction with MRP implementation.

All in all, although the literature survey demonstrated that the extent of the variance is high, or not all companies attain such benefits.(Anderson & Schroeder, 1984; Duchessi et al., 1989), the findings of the present study partly support this claim. Our findings indicate that there is significant difference amongst MRP users in some and not all tangible and intangible benefits obtained from the implementation of MRP systems.

To this end, we have completed an in depth analysis of the benefits obtained from MRP implementation by Egyptian manufacturing companies, but have not taken account of how much was invested in order to take advantage of the expected potential benefits and changes from MRP implementation. Therefore, the next section will be intended to discuss and analyse the costs of MRP installation in the Egyptian manufacturing companies.

6.3 MRP implementation costs

The findings in this section are divided into three headings:

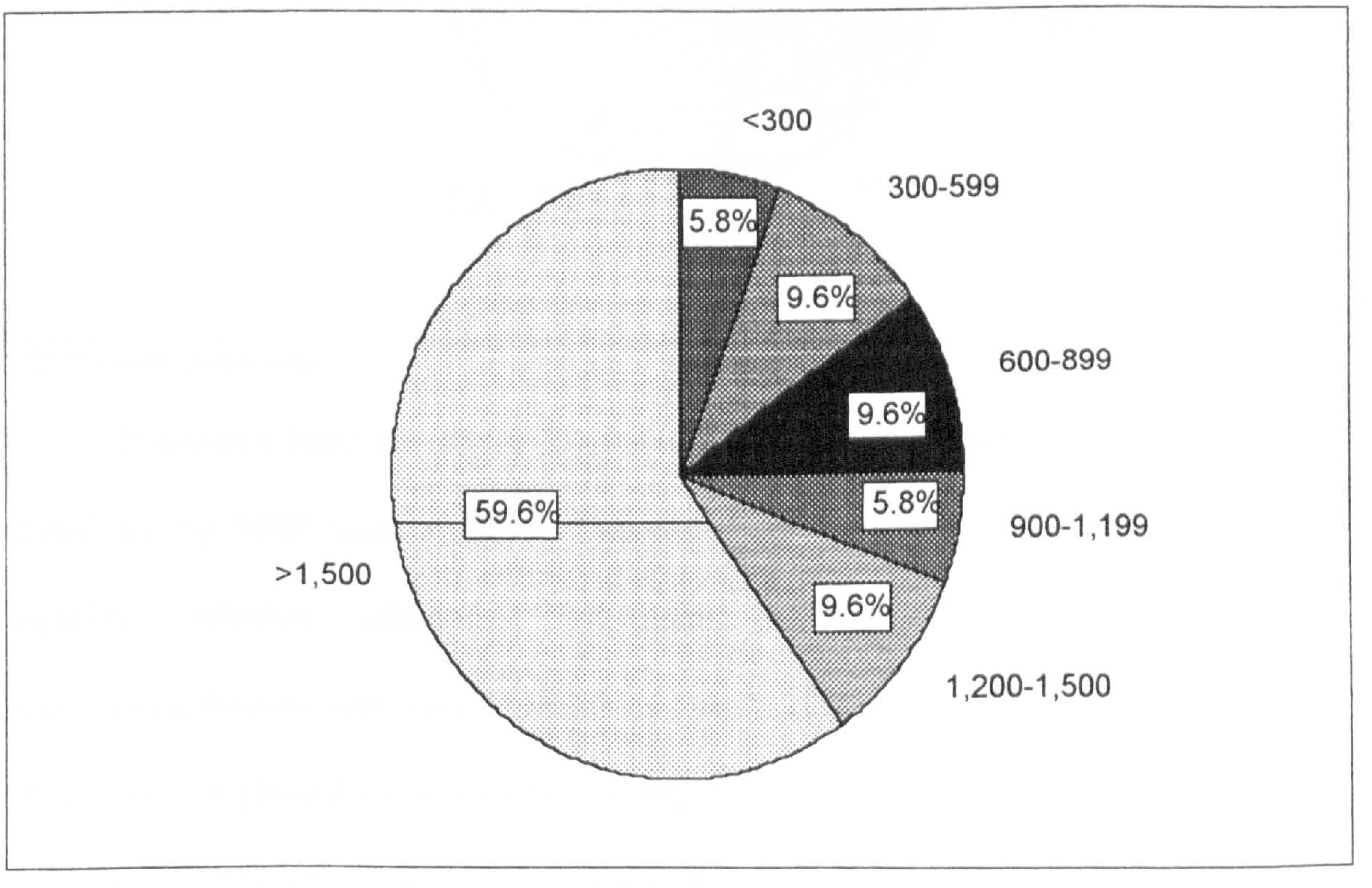
- The costs of MRP installation and the expected substantial additional investment over the next three years.
- The relationship between company size factors and MRP installation costs.
- Comparison of the results of the current study with those obtained by previous studies.

6.3.1 The analysis of the costs of MRP installation and the expected substantial additional investment over the next three years

Since it is generally believed that MRP implementation benefits are not without considerable costs (Schroeder et al., 1981; Laforge and Sturr, 1986; Sum and Yang, 1993; Ang et al., 1995), two of the questions in the survey were related to MRP implementation costs. One of them was:

How much has your company spent to install MRP in your facility?, the other question was: is an additional investment intended in MRP systems (hardware/software) over the next 3 years?, if yes, why and how much. Accordingly, the following discussion presents with in-depth analysis the responses for the previous two questions, respectively.

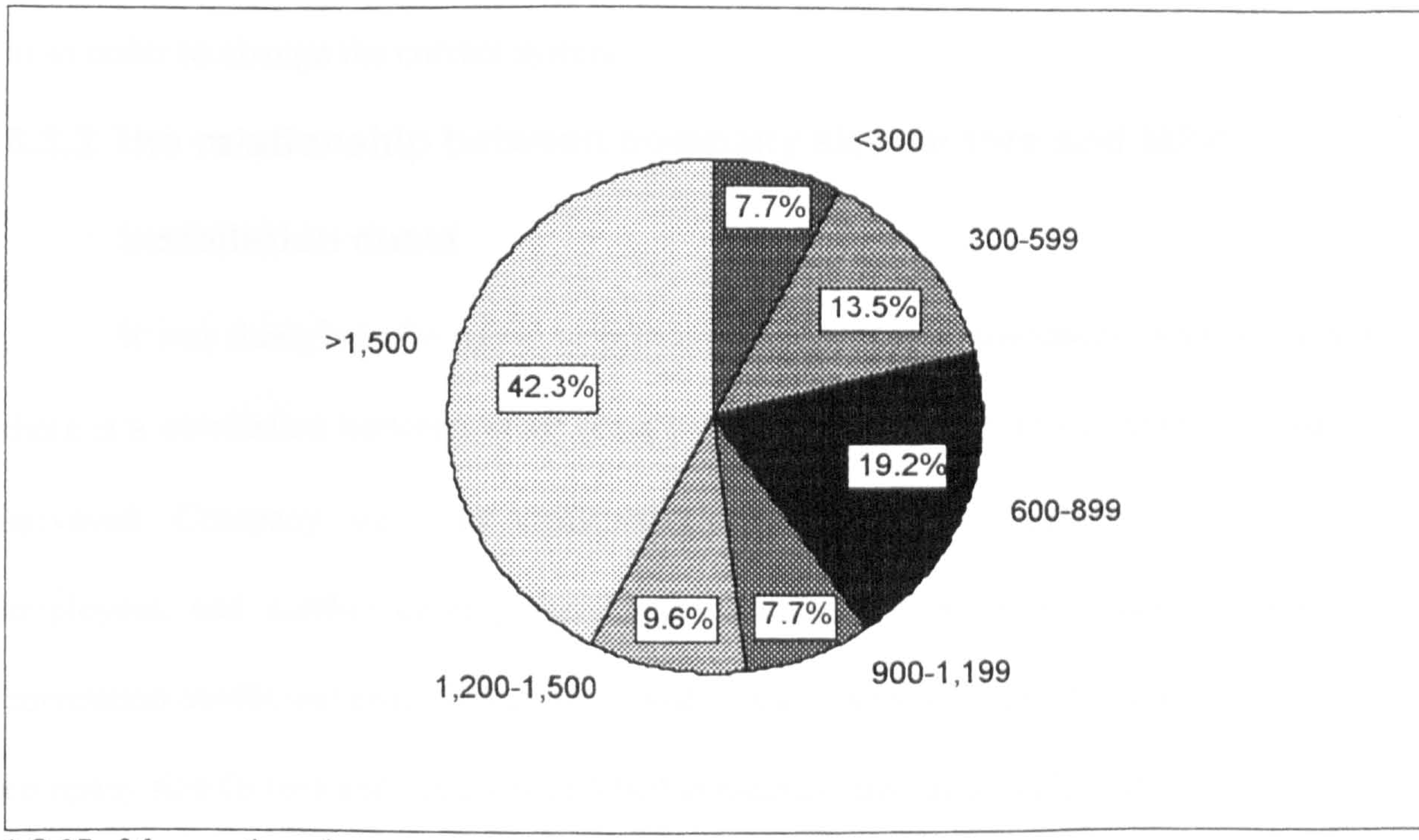
Figure 6. 1 The current MRP investment (hardware, software and personnel costs). Investment (L.E. '000)*.



* Q 26 of the questionnaire.

According to Figure 6.1 we can categorise MRP users into three groups in terms of the range of how much is spent on MRP system installation. The smaller group, companies who had spent less than L.E. 600,000 (15.4% of firms); the medium group of 25.0% who had spent between L.E. 600,000 and L.E 1,500,000; and the larger group, 59.9% of the total, who had spent more than L.E 1,500,000.

Figure 6. 2 An additional investment over the next 3 years (L.E .000)*.



* Q 27 of the questionnaire.

It appears from the above Figure (6.2) that the additional investment is more spread among MRP users in Egypt. Therefore, the response to the research questions regarding whether additional investment is intended for MRP systems (hardware/software) over next 3 years?, is "yes". This result supports our finding that MRP users are pleased and expect further improvements from MRP implementation.

Furthermore, the respondents were asked to determine why their companies were prepared to further investment. 43 out 52 MRP companies reported that the main reason behind preparing an additional investment over the next three years is to extend the current MRP system, while the rest of them (i.e. 9 MRP companies) reported that the main reason behind that is to change the current MRP system. This result concurs with the findings of Sum and Yang (1993), who reported that MRP companies in Singapore were prepared to further investment whether in order to extend the current MRP system or in order to change the current system.

6.3.2 The relationship between company size factors and MRP installation costs

It was thought to be useful to take a further step and investigate whether or not there is a correlation between MRP costs and the company size in the MRP companies surveyed. Company size was measured by total company sales, total number of employees, and number of employees in production and inventory control. Therefore correlation coefficient analysis was employed to state the association between each of the company size factors and the costs of MRP implementation as it is illustrated in Table 6.9 below.

Table 6. 9 Spearman's Correlation Coefficient between MRP cost and the company size factors.

Item relationship	*r*	Significant Level
Total company sales	.03	N.S.
Total number of employees	-.05	N.S.
Number of employees in P&I C	.003	N.S.

N.S.: Not Significant at .05 level.

It can be seen from Table 6.9, that the relationships between the costs of the MRP system (MRP installation cost + the additional investment) and the company size factors are low (r = .03, -.05 and .003, $P>.05$). Manufacturing companies do not necessarily have to be big in order to spend more on implementing MRP systems. Company size does not seem to predict the costs related to implementing MRP. This may stem from the fact that all companies in the survey are state-owned, with the Egyptian government providing them with grants, incentives etc. in implementation of new technologies. As such, these companies can freely fund their MRP implementation costs without much restriction.

This result is contrary to that of Sum and Yang study, (1993). Their results show a strong relationship between the company size and the costs of MRP implementation by the Singaporean manufacturing companies.

6.3.3 Comparison with previous studies

For comparative purposes, the findings in two previous studies concerning the costs of MRP implementation in the US (Schroeder et al., 1981; Laforge and Sturr, 1986) are displayed alongside our findings. Table 6.10 illustrates the comparison of costs of MRP installation in the Egyptian and the US companies.

Table 6. 10 The comparison of the costs of MRP systems installation in different contexts (in $ 000).

	Egypt (Present study)	US	
		Schroeder	Laforge
Mean	354*	375	623

* The average investment in $ = (The average investment in Egyptian pound L.E 1,200,000/ 3.39 [3])

Table 6.10 shows the current average investment of MRP system of the three studies. It indicates that Egyptian companies spent less than their peers in the US. This result is consistent with our findings in Chapter 5 (see section 5.10) which indicate that the Egyptian users are still relatively beginners. The Egyptian investment in MRP is less than their peers in the US where an advanced stage of MRP system has already been

[3] For comparative purposes the cost of MRP implementation in Egypt was calculated by $ currency. $1=L.E.3.39 (The average investment in Egyptian pound = L.E 1,200,000)

implemented. This is reflected in an expensive hardware and software and an extensive training as well.

6.4 Summary and conclusions

The aim of this chapter was to assess the effectiveness of MRP implementation in Egyptian manufacturing companies. In this connection, two main issues were investigated from the point of view of MRP users:

- Estimating the real benefits obtained from MRP implementation and the costs spent on MRP installation by Egyptian manufacturing companies.
- Testing hypothesis concerning the benefits obtained from MRP implementation.

To investigate the above issues, statistical techniques were extensively performed more than the previous studies to provide the highest statistical significance of the results of the issues under investigation. Having discussed the statistical results of the previous two issues, the following is a summary explaining the importance of findings:

1. The study partly demonstrates that not all MRP users attain same benefits, and also there is no relationship between company size and the costs spent on MRP installation.

2. Compared with the previous studies our study is the first large-scale study to concentrate on specific MRP benefits (nineteen measures of the benefits of MRP implementation) using extensive statistical techniques. In addition, it is as an attempt to fill the gap relating to the scarcity of benefits studies in the literature.

3. The study demonstrates that the effectiveness of MRP practices does not seem to be restricted to manufacturing companies in developed countries. The results indicate that the Egyptian manufacturing companies had received some success, at least up to the

present, and expect to achieve more improvements in their business performance because of MRP implementation in the future.

4. Our findings provide strong evidence that MRP users in Egypt, Singapore and USA are not only pleased with the improvements which were derived from MRP implementation, but also, optimistic concerning further improvements.

5. The analysis of the relationship between MRP cost and company size provides evidence that it is not necessary for the company to be too big in order to spend more on MRP implementation.

6. The findings show that although inventory control was the factor that received the highest satisfaction ratings cverall, nevertheless inventory control managers perceived the lowest level of satisfaction with MRP implementation concerning improving their ability to perform in their job. Master scheduler users recorded the highest level of satisfaction regarding achieving better ability to meet volume/ product change.

7. Our findings indicate that production and inventory control managers are not satisfied with the role of MRP implementation for improving product quality measure.

8. The study provides strong evidence that MRP benefits seem to be not restricted to the electronic and engineering industry as it was generally believed but those benefits can be attained by the other manufacturing industry sectors such as the textile and food industries.

Finally, taking account of the results of data analysis of this chapter one can conclude that the implementation of MRP systems by Egyptian users seems to be effective because our survey indicates that users believe that the expected benefits have been obtained. However, it is both interesting and relevant to explore and examine the explanatory variables of MRP system effectiveness. Consequently, the next chapter (Chapter 7) explores and examines the relationships between a set of uncertainty, organisational, implementational, technological, and human variables and the benefits obtained from MRP implementation.

CHAPTER SEVEN

Data Analysis

The MRP Benefit- Determinant Relationships

7.1 Introduction

This chapter is intended to test empirically the key hypothesis that the uncertainty, organisational, implementational, technological, and human variables do not correlate with the benefits obtained from MRP implementation in a linear manner (hypothesis # 2 - - see section 4.3.3 in Chapter 4). This is done by constructing a series of mathematical models for both MRP benefits measures (tangible and subjective benefits) using Alternating Conditional Expectation (ACE) technique as an advanced statistical modelling technique that may increase the model fit to the data by approximating the optimal transformations for the independent and dependent variables in contrast with the other regression techniques that try to satisfy the model assumptions only (Sum et al., 1995). Four specific objectives were pursued using this approach:

- to reduce statistically the number of independent variables (determinant variables) and dependent variables (MRP benefits) prior to the regression analysis using ACE,
- to generate ACE models for the benefits obtained from MRP implementation,
- to explore and examine the MRP benefit-determinant relationships, and
- to compare our findings with the relevant previous studies.

In summary, this chapter of the research has attempted to explore and examine the MRP benefit-determinant relationships by using the ACE technique and this may help to find out new insights concerning the relationship between the benefits and their determinants within Egyptian manufacturing companies.

7.2 A suggested model framework

It is interesting to recapitulate the suggested model framework of determinant variables of MRP implementation benefits prior to using the ACE technique for testing the relationships among MRP benefits and their determinants. Table 7.1 shows the determinant variables and the MRP benefits:

Table 7. 1 The framework of determinant variables of MRP implementation benefits.

Determinant Variables	Type*	MRP Implementation Benefits	Type*
Uncertainty Determinants		***Tangible Benefits***	
Product characteristics diversity	O	Inventory turnover	N
Amount of aggregate product demand	O	Delivery lead time (days)	N
Machine downtime	O	Percent of time meeting delivery promises (%)	N
The standard of raw material (quality)	O	Percent of orders requiring "splits" because of unavailable material (%)	N
Behaviour of people within the factory	O	Number of expediters (number of people)	N
Reliability of plant within the factory walls	O	***Subjective Benefits***	
Capacity constraints	O	Improved competitive position	O
Organisational Determinants		Reduced inventory costs	O
Company age	O	Increased throughput	O
Company size	O	Improved product quality	O
Type of products	C	Improved productivity	O
Type of Manufacturing	C	Better ability to meet volume/ product change	O
Layout	C	Better production scheduling	O
Company complexity	O	Reduced safety stocks	O
Organisational arrangements	C	Better cost estimation	O
Organisational willingness	C	Improved co-ordination with marketing and finance	O
Implementational Determinants		Improved your ability to perform in your job	O
Years in implementation	O	Reduced informal systems for materials management/ inventory/ production control	O
Implementation strategy	C	Increased BOM/inventory/MPS accuracy	O
Degree of data accuracy	O	Increased information on which to base decisions since MRP has been implemented	O
Initiator of MRP effort	C		
Software/hardware vendors support	O		
Implementation problems	O		
Technological Determinants			
Degree of integration among MRP modules	D		
Source of system	C		
System cost	O		
Additional investment over next 3 years	O		
User class	C		
MRP system features	C		
Human Determinants			
The previous experience with the automated information systems	O		
User involvement	C		
Degree of utilising the outputs of MRP	C		
Education and formal training	C		
User support	C		

***O** refers to ordinal variable **C** refers to categorical variable **D** refers to discrete variable **N** refers to numerical variable

7.3 Factor Analysis (*FA*)

The preceding sub-section shows that there are a large number of determinant variables and MRP benefit measures (as shown in Table 7.1). Therefore, a series of Factor Analyses (*FA*) was carried out as in (Schroeder et al., 1981; White et al., 1982; Duchessi et al., 1988; Sum et al., 1995), to reduce statistically the large number of determinant variables and MRP benefits to some smaller numbers by determining which relate to each other and which appears to measure the same thing (Emory, 1985), and to facilitate the interpretation process of the relationships under the investigation (Hair et al., 1992). This was done prior to the regression analysis by ACE technique[1]. In general terms, Factor Analysis has been used to determine the number of factors required for a data set and to rotate them to facilitate the interpretation of factors (Everitt and Dunn, 1991), and this was done in the current study. It was carried out separately for the subjective benefits, uncertainty, data accuracy, implementation problems, vendor support, and organisational, technological & human variables. To do this, five steps were carried out respectively as illustrated below:

- the appropriateness of running a Factor Analysis (*FA*),
- the number of factors to be extracted,
- the criteria of the significance of factors to be loaded,
- the constructed factors, and

[1] There is no widely accepted technique for dealing with incomplete data (Johnson and Wichern, 1992). However, as a part of this study involves comparing the Egyptian survey with previous studies such as Schroeder et al. (1981); White et al. (1982) and Sum et al. (1995). I have chosen to adopt the same strategy as used by them i.e. replacing missing values with the mean value from other respondents.

• results of the Principal Components of Factor Analysis.

7.3.1 The appropriateness of running a Factor Analysis

As pointed out by several writers such as Kim & Muller (1994) and Hutcheson (1997), the first step in Factor Analysis should be testing the appropriateness of the data collected. They mentioned that a number of statistical indicators can be used to provide evidence of the overall appropriateness of the model and also which variables should be included or excluded from the analysis. The Bartlett's Test of Sphericity tests if there is a large or small correlation between variables. When the value of Bartlett's statistic is not significant there is little correlation between the variables and vice versa (Hutcheson, 1997).

The Kaiser-Meyer-Olkin (K-M-O) measure of sampling adequacy is another one of these statistical indicators which indicates whether the overall approach of Factor Analysis is likely to be worthwhile and whether each variable is worth including. It is characterised by providing an indication of the appropriateness of the data set as whole and each variable, where the overall values of the K-M-O scores which are less than 0.50 indicate that a Factor Analysis (*FA*) is not worth pursuing the data. A variable with a K-M-O value of less than 0.50 should be excluded from the analysis. The K-M-O scores for individual variables are provided on the diagonals of the Anti-image correlation matrix (see Appendix D).

By computing the Bartlett's Test and the K- M- O technique separately for the subjective benefits, uncertainty, data accuracy, implementation problems, vendor support, and organisational, technological and human variables, the results indicate that all the values of Bartlett's statistic are significant and also all the K-M-Os are ≥ 0.60 for each data set and are ≥ 0.50 for each variable (see Appendix D), which means that all variables are likely to be worthwhile for running Factor Analysis.

7.3.2 The number of common factors to be extracted

The second step in Factor Analysis is to determine the factors needed to represent the data. To do this, the Principal Component (*PC*) method of Factor Analysis is the most frequently approach. By this method, a given set of variables is transformed into a new set of composite variables or (principal components) that are not correlated with each other (Emory, 1985), in other words, to transform a set of correlated variables into a set of uncorrelated variables (Flury and Riedwyl, 1988). The first Principal Component, *PC* (*1*), is the combination of variables accounting for the variance[2] in the data set as a whole. *PC* (*2*), is the linear combination of the variables that are uncorrelated with *PC* (*1*), and accounts for the maximum amount of the remaining variation not accounted for by *PC* (*1*), and so on. (Hutcheson, 1997)

In order to determine the number of factors needed to represent the data, there are two criteria are employed (Emory, 1985; Hair et al., 1992). The first criterion is the percentage of total variance which is explained by each, this is labelled Eigenvalue. The factors will be considered significant on the basis that they account for variances equal to or greater than one, and the second one is the percentage of variance which is attributable

[2] Variance of a given variable is a measure of its variation in the data. The variance accounted for by the new variable is greater than the variance accounted for by any other variable. Therefore, it accounts for the maximum of the total variance (Sharma, 1996).

to each factor, when the last factor accounts for less than 5 percent of variance we arrive at the end of factoring procedure. The last column in the initial statistics indicates the commutative percentage of variance attributable to that factor and those that precede it.

On this occasion, Hair et al. (1992) said that the analyst can consider as satisfactory a solution that accounts for 60 per cent of the total variance (and in some instances even less) in the social science, where information is often less precise. This will be displayed in tables 7.2 and 7.3 consecutively below:

7.3.2.1 The number of factors to be extracted for MRP benefits

Since the data on tangible benefits measures is numerical, Factor Analysis technique was used only for the subjective benefits measures where the data is ordinal. Table 7.2 indicates that five factors out of fourteen subjective benefits variables were extracted with Eigenvalue of one, or more than one for each. The commutative percentages of variance accounted by the extracted factors are 60.6 per cent for factors relating to the subjective benefits.

Table 7.2 Number of factors extracted and the percentage of variance explained for subjective benefits.

Factor*	Eigenvalue	% of variance	Cum. %
1	2.53	18.1	18.1
2	1.97	14.1	32.2
3	1.40	10.0	42.2
4	1.37	9.8	52.1
5	1.18	8.5	60.6

* The five extracted factors represent the factors needed to represent the data related to the subjective benefits based on both the Eigenvalue which estimates the amount of total variance explained by the factor) and the percentage of variance which estimates the amount of variable variation in the data. Those factors are discussed in detail in Appendix D.

7.3.2.2 The number of factors to be extracted for determinant variables

Table 7.3 indicates that three factors out of seven uncertainty variables, four out of nine data accuracy variables, three out of five vendor support variables, five out of fourteen MRP problems variables and five out of thirteen organisational and technological and human variables were extracted with Eigenvalues of one or more than one for each. The commutative percentages of variance accounted by the extracted factors are ≥ 60% for factors relating to the determinant variables as shown in Table 7.3 below.

Table 7. 3 Number of factors extracted and the percentage of variance explained for determinant variables.

Factor*	Eigenvalue	% of variance	Cum. %
Uncertainty			
1	1.89	27.0	27.0
2	1.33	19.1	46.0
3	1.02	14.6	60.7
Data accuracy			
1	2.18	24.3	24.3
2	1.59	17.7	42.0
3	1.06	11.8	53.9
4	1.03	11.5	65.4
Vendor support			
1	2.14	35.8	35.8
2	1.30	21.7	57.5
3	1.00	16.7	74.2
MRP Implementation Problems			
1	2.60	18.6	18.6
2	2.04	14.6	33.2
3	1.80	12.9	46.0
4	1.63	11.7	57.7
5	1.06	7.6	65.3
Organisational & Technological & Human			
1	2.76	21.2	21.2
2	1.93	14.9	36.1
3	1.39	10.7	46.8
4	1.09	8.4	55.2
5	1.03	7.9	63.1

* The twenty extracted factors are discussed in detail in Appendix D.

7.3.3 The criteria for the significance of factors to be loaded

In this stage, the researcher has to decide on which factor loadings are to be considered to represent variables in each factor. Factor loadings indicate how much weight is assigned to each factor based on the coefficients used to express a standardised variable in terms of the factors, where factors with large coefficients for variable are closely related to that variables (Hutcheson, 1997). Several writers such as Hair et al. (1992); Kim and Mueller (1994) and Lascu and Giese (1995), indicated that factor loading with coefficients equal to or greater than ± 50 are considered very significant. Accordingly, the considered factor loadings in this research are ± 50 or above. On this occasion, Hair et al. (1992) mentioned that variables with higher loading may have a great impact on the name of the label for the representative factor.

7.3.4 The constructed factors

At this stage we could pick the factor matrix to state the factors that may be correlated with many variables. But the factor matrix is not easy to assign any description to the factors. So, the technique of rotation can be used which can help us to select the variables for each factor and to transform the factors to make them more easily interpretable (Hutcheson, 1997). The Varimax rotation technique was employed to magnify the factor loadings by maximising the variance (i.e. a measure of dispersion of a variable) (Hair et al., (1992); or to minimise the number of variables which have a high loading on a factor, and to facilitate the interpretation of the identified factors (Hutcheson, 1997).). The rotated factor matrix provides a much clearer interpretation of the results as can be seen in Tables 7.4 and 7.5 consecutively, for both the subjective benefit measures and the determinant variables.

Table 7. 4 Subjective benefit measures factor loadings.

	Factors*					Communality**
MRP Success Measures	1	2	3	4	5	
Increased throughput	.75					.60
Improved product quality	.67					.49
Better cost estimation		.70				.58
Improved co-ordination with marketing and finance		.78				.70
Better production scheduling			.70			.60
Reduced safety stocks			.68			.74
Reduced informal systems for materials management/ inventory/ production control				.74		.69
Increased BOM/inventory/MPS accuracy				.65		.58
Reduced inventory costs					.79	.70

* The values underneath each factor are correlation coefficients between the factor and the variables. These correlation coefficients are called loadings. The keys of the five factors are as follows: operational efficiency, co-ordination, manufacturing planning and control, formal system and inventory costs, successively. This is depicted in detail in Figure 7.1.

** Communalities mean estimates of the variance in each variable which is explained the five factors e.g., with variable (increased throughput) the communality is .60 indicating that 60 percent of the variance in this variable is statistically explained in terms of factors 1, 2, 3, 4 and 5.

Table 7. 5 Determinant variables factor loadings

	Factors*								Communality
Determinant Variables	1	2	3	4	5	6	7	8	
Uncertainty									
Product characteristics diversity	.72								.64
Amount of aggregate product demand	.73								.62
The standard of raw material	.71								.53
Machine downtime		.65							. 56
Capacity constraints		.80							.68
Behaviour of people within the factory			.70						.57
Reliability of plant within the factory			.74						.68
MRP Implementation Problems									
Poor training/education on MRP				.82					.72
Lack of suitability of hardware				.63					.53
Lack of suitability of software				.77					.73
A lack of support from top management					.75				.73
Lack of support from production					.78				.68
Lack of support from marketing					.63				.65
Lack of communication						.73			.60
Lack of information technology expertise						.75			.77
Lack of support from supervisor/foreman							.76		.69
Lack of company expertise in MRP							.66		.67
Lack of involvement from vendor								.77	.71
	9	10	11	12	13	14	15	16	
Organisational &Technological & Human									
Sales	.62								.52
Number of P & I C employees	.85								.81
Number of items per product	.69								.63
User class**		.65							.54
Degree of integration		.70							.57
Previous experience			.84						.73
Number of BOM levels				.75					.63
Years in operation					.75				.61
Vendor Support									
We expected more extensive vendor support						.76			.68
We experienced a vendor software support discontinuance problem						.73			.63
Vendor instructions interpret their software product							.77		.74
Vendor personnel efficiently resolved software problems							.90		.84
The vendor provided conversion of our data into the new system								.93	.88

* The keys of the sixteen factors are as follows: the required products, capacity uncertainty, reliability uncertainty, technical problems, management support problems, MRP expertise problems, people support problems, active vendor involvement problems, company size, stage of development, experience, BOM level, company maturity, vendor support availability, active vendor proficiency and vendor experience, successively. This is depicted in detail in Figure 7.2.

** For analytical purposes user class was entered to the analysis as an ordinal variable as in Duchessi et al. (1989) and Sum et al. (1995).

Table 7.5 : (Continued)

	Factors*				Communality
Determinant Variables	17	18	19	20	
Data Accuracy					
Capacity data	.79				.64
Vendor lead times	.76				.61
Production lead times	.63				.50
Bill of material records		.69			.58
Inventory records		.68			.76
Market forecasts		.75			.77
Master production schedule			.87		.79
Routing/Work centre data			.63		.56
Shop floor control data				.84	.74

* The keys of the four factors are as follows: supply planning data, demand planning data, schedule execution data and operating execution data, successively. This is illustrated in detail in Figure 7.2.

7.3.5 Results of the Principal Components

The last stage of running Factor Analysis is to get the interpreting factors. By matching the subjective benefit measures and the determinant variables of each factor in Tables 7.4 and 7.5 to their description, Figures 7.1 and 7.2 show that nine subjective benefit measures were collapsed into five dependent measures and forty determinant variables were collapsed into twenty independent determinant variables. These factors will be used in a consecutive analysis (ACE analysis).

Figure 7. 1 The standard subjective benefit measures for MRP implementation[3]

Factor 1: Operational Efficiency (18.1%)
Increased throughput
Improved product quality
Factor 2: Co-ordination (14.1%)
Better cost estimation
Improved co-ordination with marketing and finance
Factor 3: Manufacturing Planning & Control (Predictability) (10.0%)
Better production scheduling
Reduced safety stocks
Factor 4: Formal System (9.8%)
Reduced informal systems for materials management/ inventory/ production control
Increased BOM/inventory/MPS data accuracy
Factor 5: Inventory Costs (8.5%)
Reduced inventory costs

* (%) Refers to the percent of variance explained by the factor

Figure 7. 2 The determinant variables affecting MRP implementation benefits[4]

Uncertainty Factors
Factor 1: The Required Products (27.0%)
Product characteristics diversity
Amount of aggregate product demand
The standard of raw material
Factor 2: Capacity (19.1%)
Machine downtime
Capacity constraints
Factor 3: Reliability (14.6%)
Behaviour of people within the factory
Reliability of plant within the factory
Implementation Problems Factors
Factor 4: Technical (18.6%)
Lack of suitability of hardware
Lack of suitability of software
Poor training/education on MRP
Factor 5: Management Support (14.6%)
A lack of support from top management
Lack of support from production
Lack of support from marketing
Factor 6: MRP Expertise (12.9%)
Lack of communication
Lack of information technology expertise
Factor 7: People Support (11.7%)
Lack of support from supervisor/foreman
Lack of company expertise in MRP

[3] The five factors are discussed in detail in Appendix D.
[4] The twenty factors are discussed in detail in Appendix D.

Figure 7.2 : (Continued)

Factor 8: Active Vendor Involvement (7.6%)
Lack of involvement from vendor
Organisational & Technological & Human Factors
Factor 9: Size (21.2%)
Sales
Number of P & I C employees
Number of items per product
Factor 10: Stage of Development (14.9%)
User class
Degree of integration
Factor 11: Experience (10.7%)
Previous experience with automated information systems
Factor 12: BOM Level (8.4%)
Number of BOM levels
Factor 13: Company Maturity (7.9%)
Years in operation
Vendor Support Factors
Factor 14: Vendor Support Availability (35.8%)
We expected more extensive vendor support
We experienced a vendor software support discontinuance problem
Factor 15: Active Vendor proficiency (21.7%)
Vendor instructions interpret their software product
Vendor personnel efficiently resolved software problems
Factor 16: Vendor Experience (16.7%)
The vendor provided conversion of our data into the new system
Data Accuracy Factors
Factor 17: Supply Planning Data (24.3%)
Capacity data
Vendor lead times
Production lead times
Factor 18: Demand Planning Data (17.7%)
Bill of material records
Inventory records
Market forecasts
Factor 19: Schedule Execution Data (11.8%)
Master production schedule
Routing/Work centre data
Factor 20: Operating Execution Data (11.5%)
Shop floor control data

* (%) Refers to the percent of variance explained by the factor

From figures 7.1 and 7.2 we can notice that some subjective benefit measures such as "improved competitive position"; "better ability to meet volume/ product change"; "increased information on which to base decisions since MRP has been implemented"; and "improved productivity" and some determinant variables such as "lack of support from finance"; "lack of clear goals for MRP effort"; "lack of vendor knowledge on MRP" "the project manager responsibility" did not load in any of the subjective benefits factors or determinant factors, namely these variables are either uncorrelated with the extracted factors or have weak correlation coefficients with them. This may mean that these benefits or determinant variables are not important from point of views MRP users in Egyptian manufacturing companies. Then, the loadings of the factors were saved as new variables for further analysis (Hutcheson, 1997), such as regression models (ACE) in our case. As a whole, after the Factor Analysis, we had five dependent benefits (tangible benefits), five constructed factors (subjective benefits), and fourteen independent variables, in addition to twenty constructed factors. In turn, regression models were then developed for each benefit separately using ACE technique as illustrated in the next sections below:

7.4 Testing hypothesis using ACE technique

It has been suggested (in Hypothesis -2) that the determinant variables such as execution data accuracy, degree of integration, planning data accuracy, technical problems, company size and people support problems do not necessarily correlate with MRP implementation benefits in a linear manner. For instance, when data accuracy deteriorates to a threshold level such that MRP users refuse to follow the recommendations produced by the system anymore, a further decrease in accuracy may not produce the same marginal or proportionate impact on benefits as before the threshold level was reached (Sum et al., 1995). Another example informed by learning theory, states that the time taken to perform a task on the *i*th occasion (Ti) is non-linear(Chatterjee and Price, 1991; Wild, 1996): as illustrated in **Equation 7. 1** below:

$$T_i = \alpha \beta^i, \qquad \alpha > 0, \qquad 0<\beta<1 \qquad \textbf{(7.1)}$$

Therefore, the organisational and labour learning occurring during the implementation of MRP system and its effect on benefits is likely to exhibit non-linear characteristics.

By formulating the foregoing hypothesis, the significance of the relationships can be tested with the ACE regression model as in Sum et al. (1995), who used this technique to analyse the MRP benefit-determinant relationships on 52 MRP users in Singapore.

As pointed out by several writers such as Brillinger and Preisler (1984); Pregibon and Vardi (1985); Fox and Long (1990) and Sum et al. (1995)[5] Alternating Conditional Expectation (ACE) estimation can be defined as an automatic tool for finding transformations from non-linear relationships into linear ones of both the response (dependent variables) and the predictors (independent variables) that maximises the multiple correlation, R^2, to achieve increased linear associations between Y (dependent) and set $X_1 \ldots\ldots, X_n$ (independent). Furthermore, it can be distinguished by the following characteristics:

- unlike other empirical methods, the ACE transformations have a much better model fit compared to models produced by previous studies produced by standard techniques such as Ordinary Least Squares and Discriminate Analysis because it is concerned with enhancing the model fit to the data rather than satisfying the model assumptions,

[5] A whole example that illustrates the key advantages of ACE over standard regression techniques and addresses the interpretation of an ACE model is presented in detail in (Appendix E).

- it may suggest new ways of modelling the dependence of the response (Y) on the predictors ($X_1 ......, X_n$), indicating the adjusted R^2 which can be used as a benchmark to ensure that the analytic functions represent the graphical ACE adequately, and also indicating the imputed P-value which is very helpful for comparisons between models,
- it provides the best transformations unambiguously, on the basis of both the quantitative evidence provided by comparison R^2 s and the subjective evidence provided by comparison of the scatterplots.
- its outputs include estimates of the optimal functions such as θ, ϕ, ψ at each data point and which may be used graphically for prediction,
- it is a powerful tool for finding transformations in multiple regression when relationships among dependent and independent variables are complex; it provides several options that can enhance understanding of complex relationships. One of these options is to force some or all the transformations to be monotonic,
- it has superior modelling capability compared to the other modelling methodologies such as multiple regression analysis and multiple analysis of variance in terms of highest R^2 and smallest P-value, and
- the best transformations are estimated without use of ad hoc heuristics. Furthermore, its outputs can be interpreted using transformation plots which are considered easier to conceptualise compared to mathematical expressions of the transformations. These plots may lead the investigator to improve an empirical model or to give him a sense of how much improvement is possible by taking more extreme steps.

To create ACE models for MRP benefits, four steps should be executed consequently as follows:

7.4.1 To decide whether a transformation is necessary

Box and Cox (1964); Wetherill et al. (1986); Carroll and Ruppert (1988); Fox and Long (1990); Sen and Srivastava (1990); Chatterjee & Price (1991) and Hutcheson (1997), indicated that the need for transforming the data arises when the original variable or the model in terms of the original variable violates one or more of the assumptions of the standard regression model. These are: normality of distributions, linearity (the relationships between variables is well approximated by a straight line) and homoscedasticity (the constancy of the error variance) or the non-linear relationship between variables is theoretically hypothesised (Chatterjee & Price, 1991). If so, transformation to normality and homoscedasticity data is necessary in order to enable us to use the standard regression techniques and allows the parameter vector β to be estimated efficiently (Carroll & Ruppert; 1988; Chatterjee & Price, 1991; Hutcheson, 1997). Therefore, the following subsections are intended to detect the previous problems as follow:

7.4.1.1 Theoretical consideration

It was hypothesised that there were underlying, non-linear relationships between determinant variables and benefits obtained from MRP implementation (see section 7.4).

7.4.1.2 Probabilistic reasons

If the original data is non-normally distributed and the variance of error is non-constant, the linear model will be distorted and the analysis will be degraded. The

Skewness method can be used to determine which data can depart from normality. It refers to the degree to which a distribution is not symmetric and which may lead to misleading results (Ratkowsky, 1983). If the ratio of the skewness to the standard error of the skew is less than -2 or greater than +2, the data can be considered to be significantly skewed and they are candidate to be transformed and vice versa. **Equation 7. 2** shows the significance of Skewness:

$$\text{Significantly Skewed Data} = \frac{Skewness}{s.e.skew} = \geq \pm 2 \qquad \textbf{(7.2)}$$

where *s.e* (standard error) denotes the square root of the variance of a sample i.e. the mean square deviation of the values of a sample from their own mean.

A positive value indicates a longer right tail to the distribution and a negative value a left tail (Hutcheson, 1997). Table 7.6 depicts the skewness statistics calculated for 44 variables represent MRP benefits and determinant variables (10:34).

Table 7. 6 Statistics to depict the significance of Skewness.

Variables	Skewness	S.E. Skew	The significance of Skewed Data
Vendor experience	1.24	.33	3.76
Co-ordination	-.60	.33	-1.82
Active vendor proficiency	2.94	.33	8.91
Inventory costs	-.58	.33	-1.76
Vendor support availability	1.45	.33	4.39
Organisational willingness	.13	.33	.39
Manufacturing P&C	-.73	.33	-2.21
Supply planning data	.68	.33	2.06
Demand planning data	.59	.33	1.79
Company size	.82	.33	2.48
Levels in BOM	.31	.33	.94
Company maturity	-2.60	.33	-7.88
Stage of development	.19	.33	.58
Formal system	.04	.33	.12
Technical problems	-1.08	.33	-3.27
Schedule execution data	.11	.33	.33
Uncertain capacity	.87	.33	2.64
Uncertain required products	.10	.33	.30
Management support problems	-1.44	.33	-4.36
Active vendor involvement	.02	.33	.06
Layout	.28	.33	.85
Uncertain reliability	.35	.33	1.06
People support problems	.74	.33	2.24
Operational efficiency	.28	.33	.85
MRP expertise problem	.25	.33	.76
Experience with automated Systems	-.25	.33	-.76
Operating execution data	1.83	.33	5.55
Organisational arrangements	.96	.33	2.91
Initiator of MRP effort	2.86	.33	8.67
Implementation strategy	.91	.33	2.76
Meeting delivery promises	.30	.33	.91
Marketing strategy	.08	.33	.24
The number of expediters	-84.	.33	-2.43
The percent of split orders	-.14	.33	-.42
Source of system	.25	.33	.76
Inventory turnover	-.33	.33	-1.00
Delivery lead times	.25	.33	.76
Utilising outputs	1.33	.33	4.03
User involvement	.11	.33	.33
Manufacturing process	1.25	.33	3.79
Years in implementation	.13	.33	.39
MRP system features	.91	.33	2.67
User Support	.30	.33	.91
Education and Training	.25	.33	.76

The results in the last column in Table 7.6 indicate that 19 out of 44 variables are significantly skewed and are candidates for transformation to reduce the Skewness. Furthermore, one of the assumptions that should be made of the data for General Linear Model (GLM) is that the response variables are independent with having an equal variance or homoscedasticity (Wetherill et al., 1986).

One of the common methods used for determining whether the variance of error is constant or non- constant (heteroscedastic) is to check for outliers in the data. (Flury and Riedwyl, 1988; Sen and Srivastava, 1990; Everitt and Dunn, 1991). The outliers mean that some individual data points are quite different from the rest of the observations (Chatterjee & Price, 1991). These outlier points may arise from coding error or unusual data points (Hutcheson, 1997). Regression analysis literature suggests that graphical methods of detecting outliers are quite time consuming and can only really be used if there are two or three variables. The Cook's Distance measure has been considered an easier and more accurate way of detecting multivariate outliers. It indicates the effect of having the particular data point in the model or not. It is calculated by first running the regression model procedure and saving Cook's Distance as a new variable using **Equation 7. 3** below:

$$C_i^2 = \frac{\sum\left(\hat{y}_j - \hat{y}_{j(i)}\right)^2}{ps^2} \qquad \textbf{(7.3)}$$

Where, C_i^2 Cook's Distance represents a measure of how much the results of all cases would change if a particular case were excluded from the calculation of the regression analysis. Ps^2 denotes the P matrix of the residual mean square s^2. y_i -y_i represents the predicted values of j which represents the variables which result from deleting the i th observations (i = 1,2,.......,n). It has been suggested that points with C_i^2 values greater than the 1 can be classified as influential point, namely, it will be outlier point (Chatterjee & Price, 1991). Table 7.7 depicts the Coo-$x_{1,....10}$ where x represents the number of Cook's measures that we had calculated as shown below:

Table 7. 7 Influence measures (Cook's Distance).

Row	Coo_1	Coo_2	Coo_3	Coo_4	Coo_5	Coo_6	Coo_7	Coo_8	Coo_9	Coo_{10}
1	.01380	.00723	.02793	.04625	.04625	.04480	.14118	.10445	.00080	.06040
2	.00686	.00146	.00080	.02107	.02107	.00507	.04703	.00395	.01355	.10711
3	.01010	.01371	.00844	.04029	.04029	.10837	.06306	.00160	.07591	.01660
4	.00199	.06487	.00157	.00502	.00502	.00407	.02666	.02077	.03576	.05440
5	.06009	.00688	.00261	.00885	.00885	.03129	.00024	.12132	.01408	.01159
6	.08663	.04452	.01595	.00520	.00520	.03853	.07483	.00036	.11886	.08289
7	.00111	.04939	.00014	.06056	.06056	.00033	.01647	.06555	.04781	.07363
8	.02320	.00248	.00000	.09509	.09509	.00235	.01411	.07235	.08178	.00877
9	.00299	.09860	.02232	.03938	.03938	.00000	.00012	.00266	.03859	.00438
10	.00457	.01805	.02004	.00566	.00566	.00069	.00841	.00546	.07434	.00898
11	.04600	1.0159	.01256	.07910	.07910	.02449	.02462	.09167	.03566	.05398
12	.01146	.00614	.00014	.02366	.02366	.00860	.10514	.07617	.00005	.10103
13	.00734	.04997	.06969	.14936	.14936	.00000	.00149	.16935	.07250	.18423
14	.09682	.05055	.06694	.19452	.19452	.09644	.08949	.20260	.02360	.00870
15	.02859	.03639	.01585	.02339	.02339	.00359	.00637	.01169	.00670	.00248
16	.19743	.10685	.01751	.12535	.12535	.01612	.37165	.22900	1.2667	.01285
17	.07995	.00460	.01687	.09012	.09012	.10557	.00401	.02798	.00108	.16476
18	.00536	.02676	.01606	.03628	.03628	.07318	.01350	.03577	.00940	.00193
19	.05284	.09218	.01129	.01155	.01155	.00703	.00003	.00026	.00277	.03221
20	.07216	.01912	.09753	.05900	.05900	.07525	.19551	.00105	.12516	.09700
21	.00071	.00756	.05678	.03811	.03811	.02429	.00345	.00103	.00049	.05756
22	.01480	.08332	.02559	.08313	.08313	.01685	.21129	.02195	.00100	.00237
23	.36849	.11884	.00154	.07842	.07842	.12684	.06395	.24313	.17391	.00557
24	.02152	.01726	1.4587	.07708	.07708	.00146	.16875	.00069	.00287	.06798
25	.16428	.08492	.38035	.00321	.00321	.11414	.00150	.04346	.33009	.00122
26	.08984	.25727	.00008	.02857	.02857	.00270	.01897	.00074	.05281	.00217
27	.11726	.01835	.07126	.05699	.05699	.00640	.00277	.00133	.00137	.02240
28	1.0468	.00525	.45505	.05608	.05608	.06304	.04322	.04129	1.1852	.05796
29	.02611	.08175	.00949	.00778	.00778	.01571	.06797	.01189	.00227	.04592
30	.08992	.00167	.04703	.02660	.02660	.03425	.02594	.02081	.00714	.04617
31	.00023	.00044	.19917	.03036	.03036	.00442	.02247	.01099	.03817	.03461
32	.16758	.00191	.00002	.06290	.06290	.04618	.01987	.00639	.00210	.01129
33	.01847	.01105	.00364	.00142	.00142	.01807	.11636	.00958	.00105	.11207
34	.01137	.00034	.06382	.05625	.05625	.01865	.03617	.00281	.13978	.00064
35	.04877	.02528	.00422	.17029	.17029	.03830	.00069	.06449	.10621	.09947
36	.22867	.17823	.57840	1.1180	.57180	.24850	.17933	.02916	.15878	.13786
37	.08469	.00268	.20095	.00219	.00219	.01951	.00283	.18447	.10536	.01318
38	.11039	.05640	.00645	.00028	.00028	.03047	.15639	.00360	.14535	.09254
39	.00017	.00245	.00526	.00267	.00267	.00170	.00919	.01803	.00286	.01148
40	.00000	.00388	.24914	.08422	.08422	.08592	.09056	.00055	.11508	.05068
41	.00042	.00388	.09987	.08415	.08415	.09844	.02510	.04244	.40579	.04412
42	.01320	.07453	.01004	.07684	.07684	.15207	.00148	.02396	.03359	.01705
43	.00159	.01336	.01497	.00163	.00163	.04330	.02053	.00080	.00099	.00141
44	.01698	.08280	.01078	.08328	.08328	.07339	.00083	.02235	.01141	.00404
45	.00003	.21602	.08155	.02423	.02423	.00016	.00657	.17081	.00000	.00638
46	.07020	.15439	.00193	.00088	.00088	.02094	.00011	.00734	.01914	.06378
47	.00000	.02171	.03901	.06475	.06475	.06300	.01009	.03185	.01374	.05105
48	.00011	.00048	.00029	.01942	.01942	.03533	.00880	.05904	.00060	.00787
49	.05424	.09739	.03906	.00981	.00981	.01678	.09474	.00420	.00935	.00721
50	.04476	.00305	.01886	.00556	.00556	.06342	.00714	.01119	.00010	.00429
51	.01525	.00030	.03458	.00541	.00541	.07557	.04202	.01657	.02013	.04385
52	.00679	.00236	.00930	.01547	.01547	.06140	.01677	.08793	.03789	.00776

The conclusion that can be drawn from Table 7.7 is that there are several observations such as (16 with Coo_9 and 28 with Coo_1) which are clearly outliers. Therefore, transforming data is needed.

7.4.1.3 Examining plots

A useful method for identifying non-linearity is to use Matrix Scatterplots which identify the form of the relationships between variables (Hutcheson, 1997). The matrices scatterplots indicate that some of the relationships among benefits and the determinant variables appear to be non-linear. For example, there appears to be a non-linear relationship between operational efficiency and data accuracy factors and between coordination and people support as shown in Figures 7.3 & 7.4 below:

Figure 7. 3 Investigating the relationship between operational efficiency and data accuracy factors with matrix scatterplots

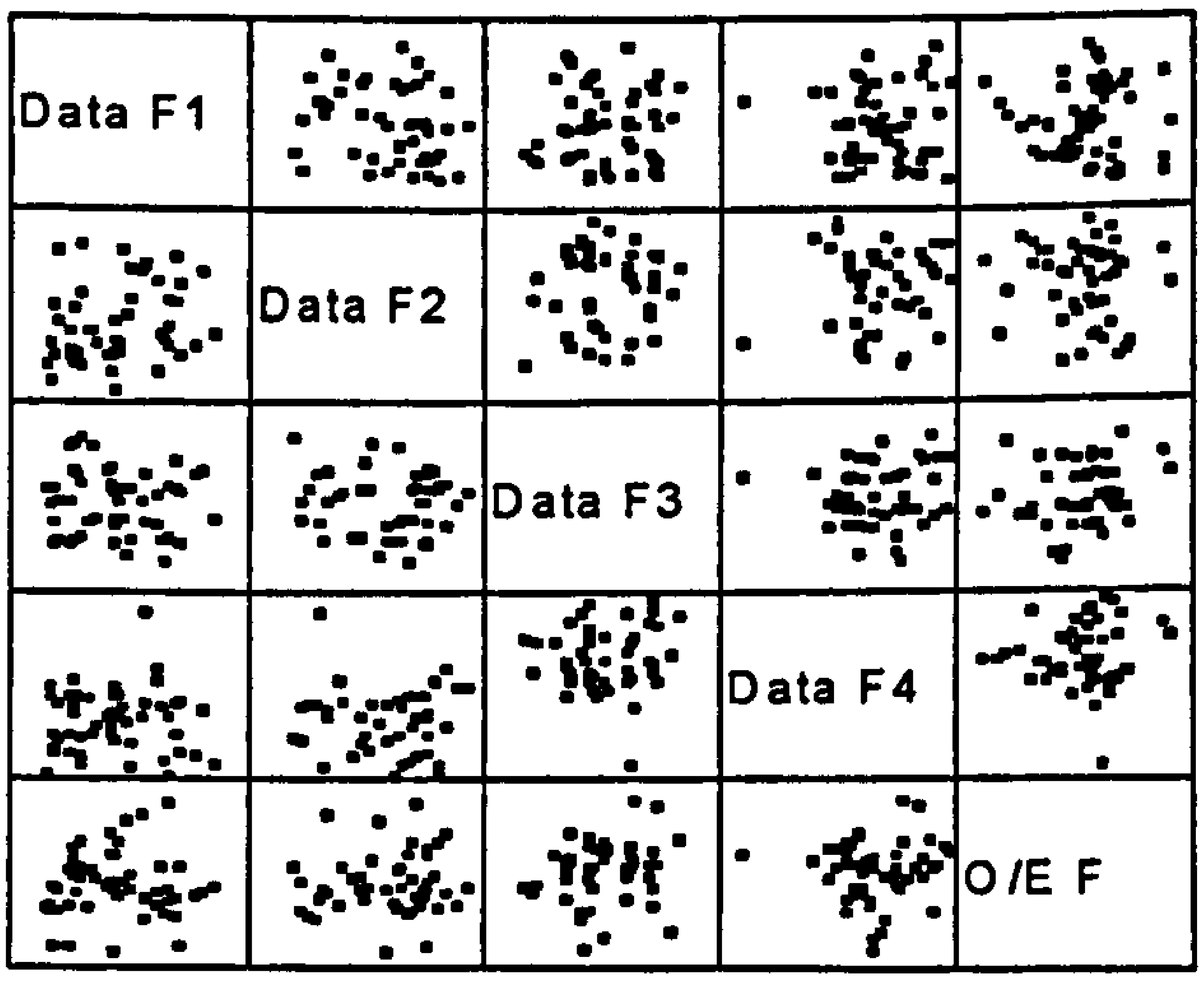
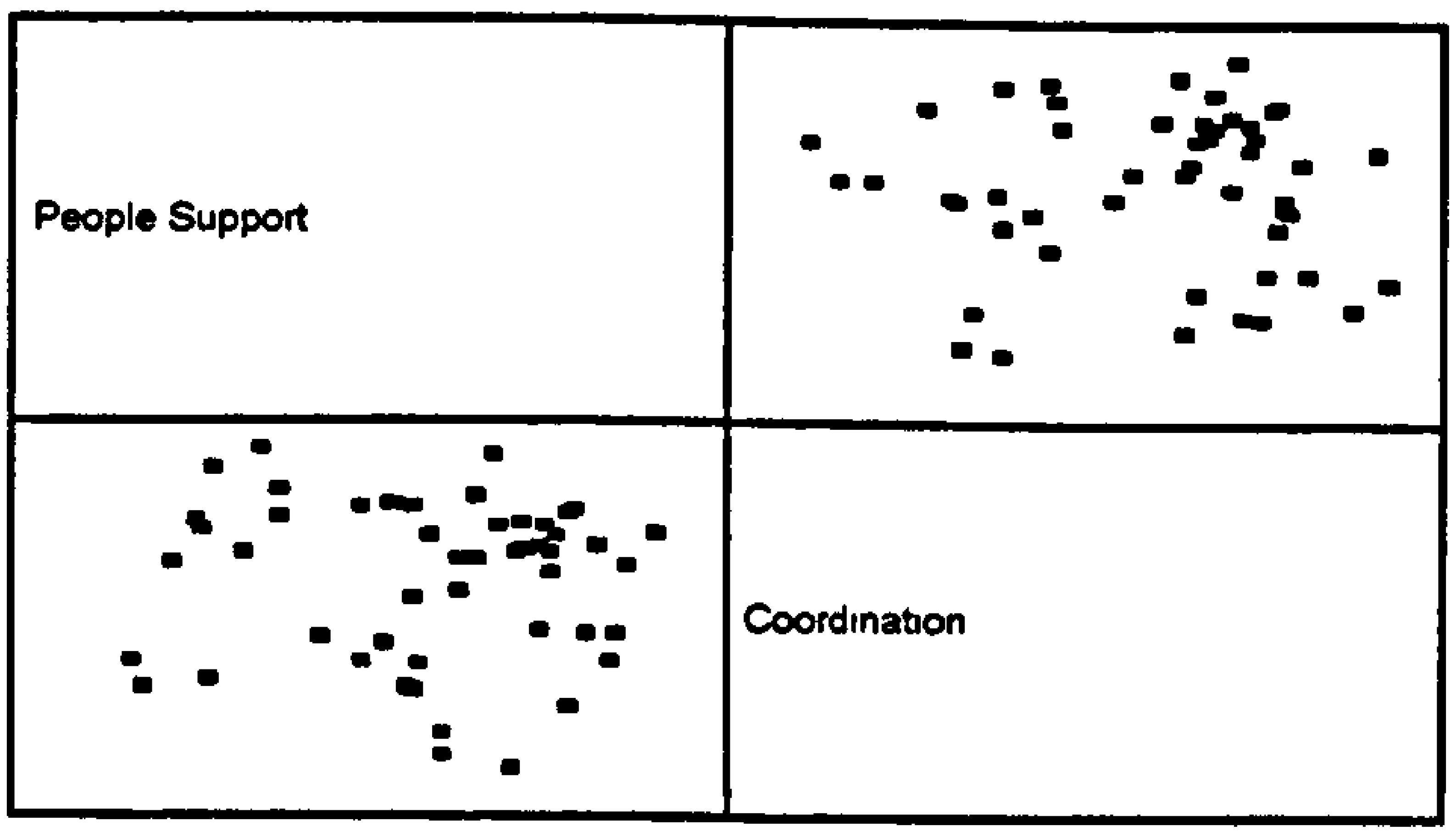


Figure 7. 4 Investigating the relationship coordination and people support factors with matrix scatterplots



The foregoing relationships can be mathematically described in a non-linear form (the parameter β_1 does not enter the model linearly). So, a regression model is non-linear as shown in **Equations 7. 4** below:

$$B = \alpha + e^{\beta 1 D} + \varepsilon \qquad \textbf{(7.4)}$$

where B is the value of operational efficiency benefit (dependent variable). D is the value of company size (independent variable). α is the value of B when explanatory variable (D) = 0. ε indicates the variability in the response variable (B) which cannot be appropriated to any of the explanatory variables in the equation. β represents the elasticity of change in B (dependent) which is expected to result from a change of one unit in D (independent) when all other independent variables are held constant. e is an analytical function (exponential).

On the other hand, the relationship between response and predictor variable can be described in a linear manner where the parameters β's enter in the model linearly. This can be represented by one of the following equations (Chatterjee & Price, 1991):

$$B = \alpha + \beta_1 D + \varepsilon \qquad \textbf{(7.5)}$$

$$B = \alpha + \beta_1 D + \beta_2 D^2 + \varepsilon \qquad \textbf{(7.6)}$$

$$B = \alpha + \beta_1 \log D + \varepsilon \qquad \textbf{(7.7)}$$

$$B = \alpha + \beta_1 \sqrt{D} + \varepsilon \qquad \textbf{(7.8)}$$

In summary, we conclude that the data of some of the variables under investigation can described in a linear manner. On the other hand, the rest of the data have the major three problems (non-normality, non-linearity and non-constant variance or heteroscedasticity), so, transformation is necessary to approximate the data to the normal distribution, to achieve linearity related to variable another and to stabilise the variance using ACE technique as in Sum et al. (1995). Therefore, the decision was made to test the relationships between benefits and the determinant variables using multiple regression analysis as in Schroeder et al. (1981) namely, before transforming data, followed by testing these relationships using ACE technique (models after variable transformation) as in Sum et al. (1995), then checking the statistical significance of comparing between the best linear models and the best ACE' models by evaluating modelling capability of the type of models using adjusted R^2 and P-values, then finally selecting the final models for MRP benefits.

7.4.2 Evaluating an ACE's model capability

The ACE model should not be blindly trusted as the best overall way to represent the dependence of the dependent variable on the independent variables. Also, it is not intended to replace the standard regression tools in the data analysis (Fox and Long, 1991). The need to evaluate the capability of ACE's modelling is required before selecting the final models for MRP benefits. To do that, we followed Schroeder et al. (1981) and Sum et al. (1995). We identified the best linear models by running all possible regression analysis models and selecting the top few models with highest adjusted multiple correlation of the response with the predictors, R^2. Then we ran ACE using the same variables determined in the best linear models. Then we compared the results of the two techniques in the light of the extracted R^2 which provides how well the model fits the population. It is a much more useful statistic for multiple regression, and can be calculated using **Equation 7.9**:

$$Adjusted\,R^2 = R^2 - \frac{P\left(1-R^2\right)}{N-P-1} \qquad (7.9)$$

Where R^2 is the coefficient of multiple regression which provides how well the model fits the sample or represents the amount of the variance in one variable which can be accounted for by the other, P is the number of explanatory variables in the model, and N is the number of cases. The adjusted R^2 is used as a benchmark for comparing the quality of the regression of b on d (before transformation) to the regression of tb on td (after transformation), where b is the benefit obtained from MRP implementation and d is the determinant variable. The results indicate that the highest adjusted R^2 s extracted by running regression analysis were 0.28 and 0.44[6] in cases of the relationships between delivery lead time benefit and all independent variables and between operational efficiency benefit with all independent variables respectively.

By running ACE using the same variables identified in the best linear models (i.e. models without transformations), the ACE models improved the adjusted R^2 as much as 0.63 (0.91 - 0.28) and 0.42 (0.86 - 0.44) percentage points respectively. These results confirm the superior modelling capability of ACE technique.

7.4.3 Selecting the final models for MRP benefits

Several writers such as Wetherill et al. (1986); Sen and Srivastava (1990) and Chatterjee & Price (1991), pointed out that it is important to recognise strategies should be taken to select candidate models in a regression analysis. The ACE technique depends upon two strategies to generate the final ACE models for MRP benefits. The first

[6] These results were extracted using OLS technique in order to get R^2 for the two dependent variables with all the forty independent variables before transformations.

strategy is forward stepwise which starts with no determinant variables in the model and first selects that χ_j which has the highest adjusted R^2 with Y and so on until there is no substantial increase in model adjusted R^2. The second is backward stepwise elimination which starts with all determinant variables in the model and deletes the less important ones one by one.

Ten final ACE models were selected by running the previous strategies consequently as depicted in Table 7.8. The parameter's coefficients for determinant variables in the ACE models and small p-values in Table 7.8 indicate that all ACE models and all determinant variables are very significant. It is interesting to note that all parameters coefficients for the determinant variables (independent) are positive because we regressed the transformed benefit measure (dependent variable) on all the transformed determinant variables (independent) as in Sum et al. (1995). Surprisingly, the adjusted R^2's and P-values are better than Cooper and Zmud (1989; 1990) and Sum et al. (1995).

For analytical purposes, we used a Dummy variable coding to recode Manufacturing Process and Marketing Strategy into a number of dichotomous variables showing the presence or absence of each category. The first was coded 0 for continuous (includes continuous production and assembly line) and 1 for intermittent (includes batch operation and job shop), the second was coded 0 for make to stock and 1 for make to order (in relation to intermediate levels for marketing strategy making to order and to stock are presented by fractional numbers).

Table 7.8 The ACE models for MRP benefits.

Determinant Variable	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
Uncertainty										
The required products[a]										
Capacity[a]		.0026			.0351					
Reliability[a]			.0045							
Org. & Tech. & Hum.*										
Source of MRP system**										
Manufacturing process										
continuos		.0088								
intermittent		.0136								
Layout										
Manufacturing strategy										
Make to oreder	.0525[b]									.0001
Make to stock	.0741									.0651
User involvement										
Utilizing MRP outputs										
Levels in BOM	.0007			.0001	.0005					.2e-4
Company maturity										
User support										
Company size[a]					.0884	.5e-4				
Stage of development[a]				.3e-5	.0003	.0049				
Years in implementation								.0035		
MRP system features										
Education and training										
Experience[a]									.0036	
Vendor support availability[a]	.0048									
Active vendor proficiency[a]										
Vendor experience[a]										
Organizational willingness										
Implementational										
Year in implementation										
Data accuracy										
Supply planning data[a]		.0001						.0013		
Demand planning data[a]							.0003	.0534		
Schedule execution data[a]			.0019							
Operating execution data[a]						.1e-4				
Implementatinal problems										
Technical[a]									.3e-4	
Management support[a]				.0250			.2e-4			
MRP expertise[a]										
People support[a]			.0034				.0002			
Vendor involvement[a]										
Implementation strategy										
Initiator of MRP effort										
Model p-value	.1e-6	.7e-5	.1e-3	.4e-9	.2e-5	.1e-5	.1e-6	.4e-5	.2e-6	.1e-6
Model adjusted R^2	0.51	0.43	0.35	0.74	0.45	0.47	0.50	0.39	0.47	0.55
Model R^2	0.56	0.48	0.41	0.78	0.50	0.52	0.53	0.43	0.50	0.61
N	52	52	52	52	52	52	52	52	52	52

[a] Constructed factor. [b] Parameter p-value. All parameter coefficients are positive.

B_1 refers to inventory turnover B_2 refers to delivery lead time B_3 refers to percent of time meeting delivery promises B_4 refers to split orders B_5 refers to number of expediters B_6 refers to operational coefficient B_7 refers to co-ordination B_8 refers to manufacturing planning and control B_9 refers to formal system B_{10} refers to inventory costs.

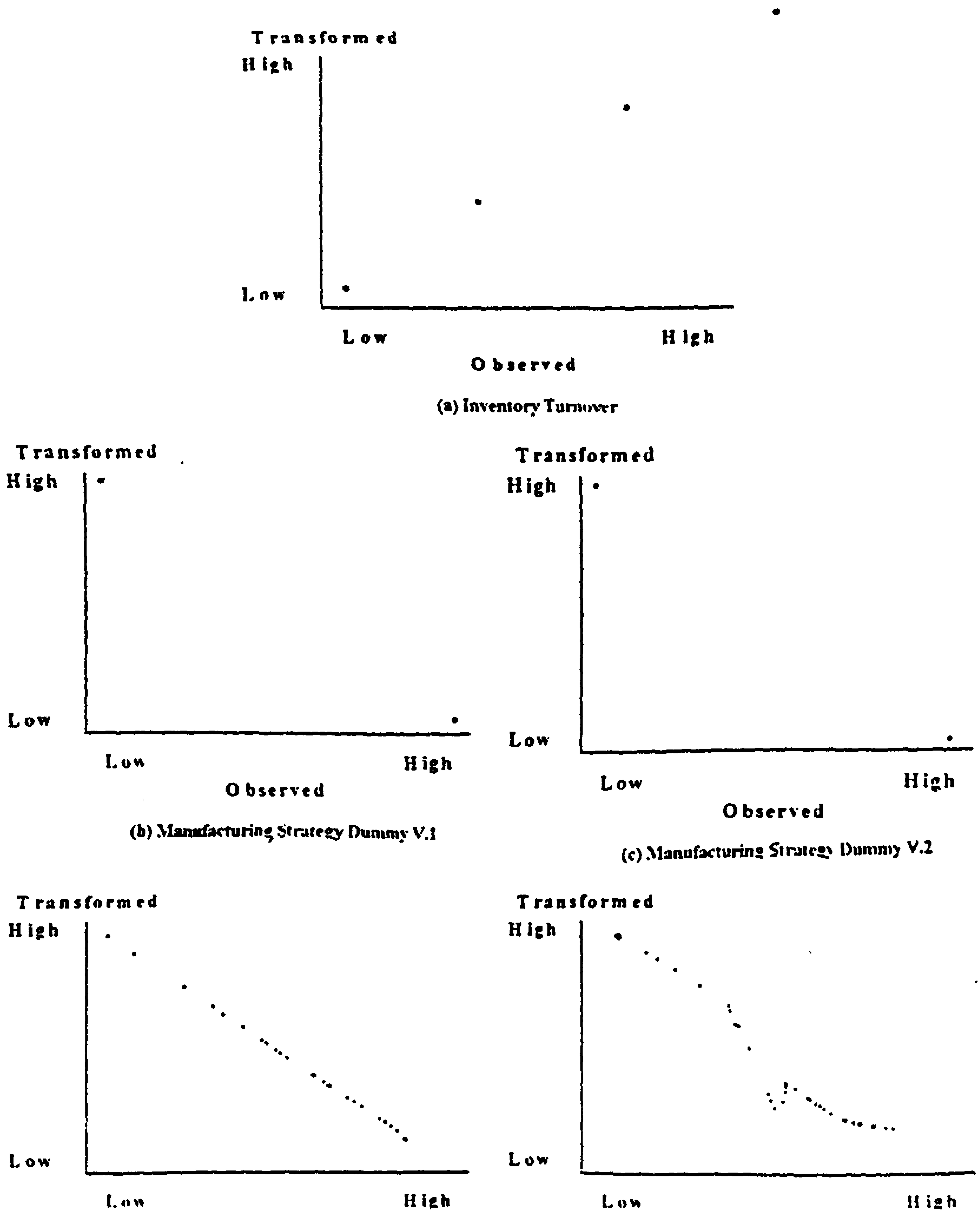
* Organizational & Technological & Human. ** Blanks in the table indicate parameter coefficients are not statistically significant (determinant variables not included in the models extracted by ACE technique).

7.4.4 The interpretation of ACE models for MRP benefits

The analytic transformations extracted from the ACE technique for determinant variables in the ten MRP benefits models are illustrated in Figures 7.5-7.14 respectively. As a whole, these figures provide us with valuable information which support our hypothesis that the benefits obtained from MRP implementation do not necessarily correlate with the determinant variables in a linear manner.

To interpret the output of the ACE models, we should look at the plots of **tb vs. b** and $\mathbf{td_v}$ **vs.** $\mathbf{d_v}$ for each v = 1,......, n variables. It is interesting to note that the transformed scores of the determinant variables in Figures 7.5-7.14 are positively correlated with their corresponding observed benefit scores. This is because of all the transformations for the benefit variables are increasing functions as shown in Figures $\mathbf{7.5_a}$ - $\mathbf{7.14_a}$ and also all parameters coefficients for the determinant variables are positive as depicted in Table 7.8 Therefore, we will interpret the transformed scores axis (y-axis) of a determinant transformation plot as if it is the corresponding "observed benefit variable" axis as in Sum et al. (1995). All in all, we only concentrate on the individual transformation plots of the independent variables (determinant variables) in order to explore and examine their effects on the dependent variables (MRP benefits) as in Schroeder et al. (1981) and Sum et al. (1995).

Figure 7. 5 Transformations for Inventory Turnover



(a) Inventory Turnover

(b) Manufacturing Strategy Dummy V.1

(c) Manufacturing Strategy Dummy V.2

(d) Levels in BOM

(e) Vendor Support Availability

7.4.4.1 Inventory Turnover

As shown in Table 7.8 the inventory turnover benefit measure is affected by manufacturing strategy, levels in BOM and vendor support availability. The results of the inventory turnover model are statistically significant, with 51.0% of the variance in inventory turnover accounted for (i.e. that manufacturing strategy, levels in BOM and vendor support availability variables had explained approximately 51.0% of changes of inventory turnover benefit measure among the Egyptian users). Figure 7.5 displays the variable transformations.

<u>7.4.4.1.1 Manufacturing strategy</u>

The difference in the parameter estimates between make to order and make to stock variables (Table 7.8) is .0216 in favour of make to order strategy, suggesting that more inventory turnover are obtained in make to order than make to stock environments. Logically, make to stock companies should operate with safety stocks of the end item for protection from stockout until components become available if the company happens to get off schedule, while make to order companies would not be able to have safety stocks of components because they do not know what end items they will be producing and when. As usual, make to order companies are achieving higher inventory turnover (the ratio of sales to the average of inventory level measured at the cost or retailed price) than make to stock companies (Dilworth, 1993). Our results concurs with Schroeder et al. 's (Schroeder et al., 1981) finding that inventory turnover is significantly better in make to order environments.

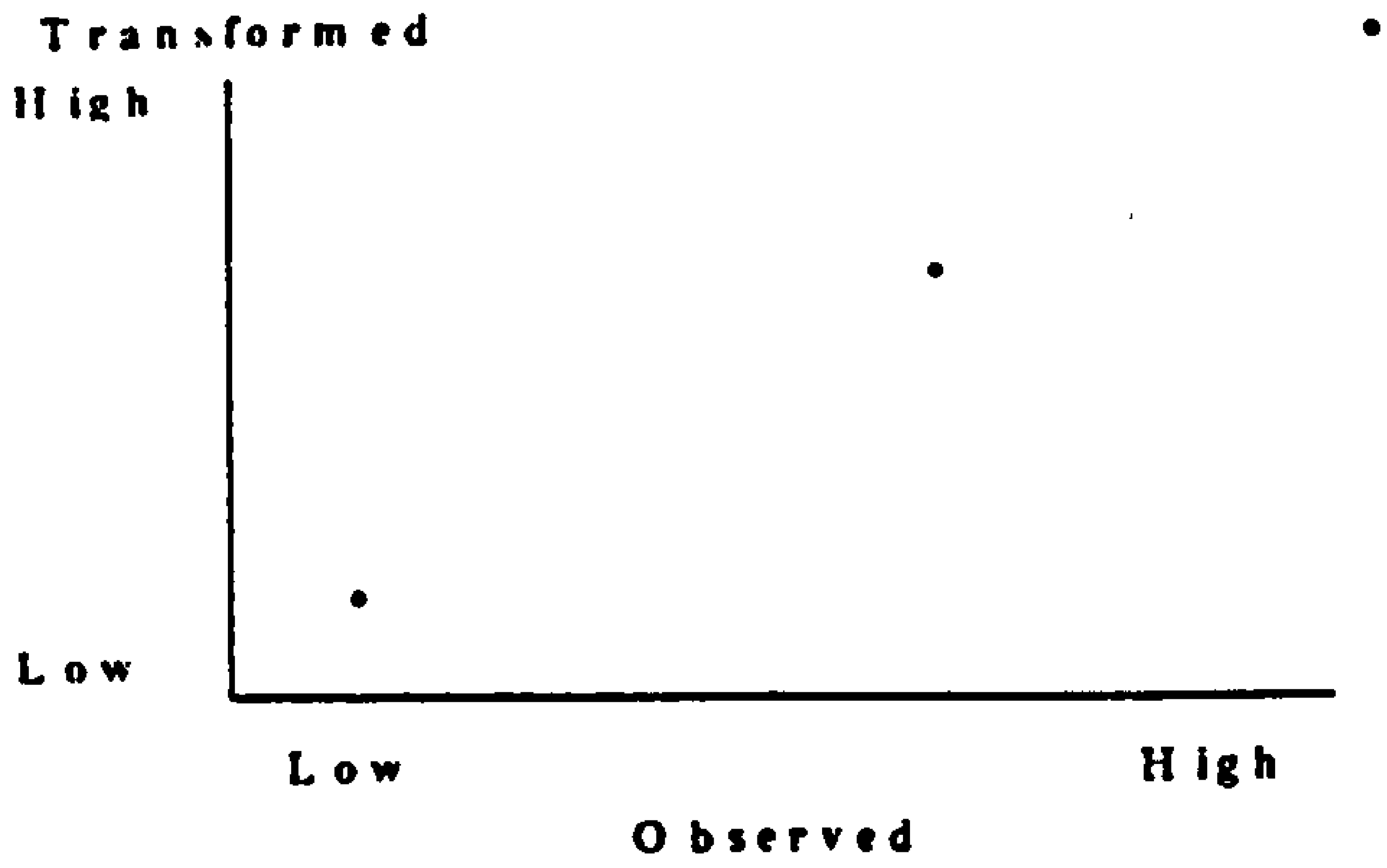
7.4.4.1.2 Levels in BOM

The levels in BOM transformation is displayed in Fig. 7.5d. This indicates that an increasing level in bill of materials has a negative impact on inventory turnover. The interpretation for the previous result may be related to the fact that more levels in the BOM means more subassemblies, more intermediates, more parts and more raw materials (Browne et al., 1996), namely more inventory investment and which may lead to less inventory turnover. This finding supports Schroeder et al. 's (Schroeder et al., 1981) finding that the complexity product structure which includes parts & components and levels in BOM has an opposite effect on inventory turnover.

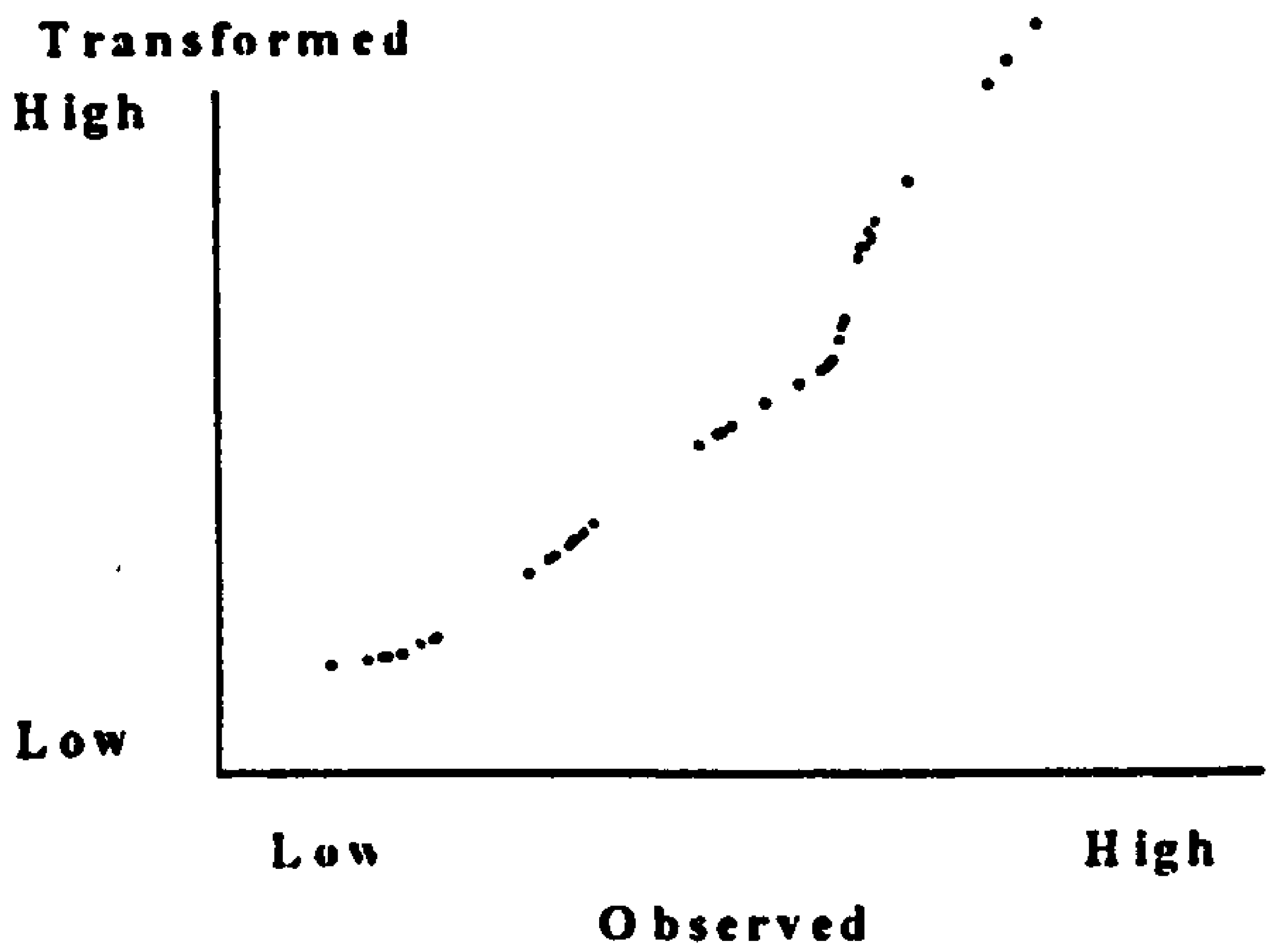
7.4.4.1.3 Vendor support availability

The non-linear transformation of the independent variable, vendor support availability, presents a very interesting insight (Fig. 7.5e). It suggests that as the vendor support increases, the inventory turnover would decrease, then increase, and then decrease again. The explanation of this result is likely to be related to the fact that as a manufacturing company is a beginner in MRP implementation, it expects high support from MRP vendors to overcome the implementation problems and which may be reflected in reducing its performance such as reducing inventory turnover. In process of time, the MRP company becomes more familiar and more successful with MRP implementation so they expect less support from the vendor. But, the company may decide to upgrade or develop its MRP system later and their reliance on the vendor support will increase again. Duchessi et al. (1986;1989) also found that the successful companies expect less support from MRP vendors.

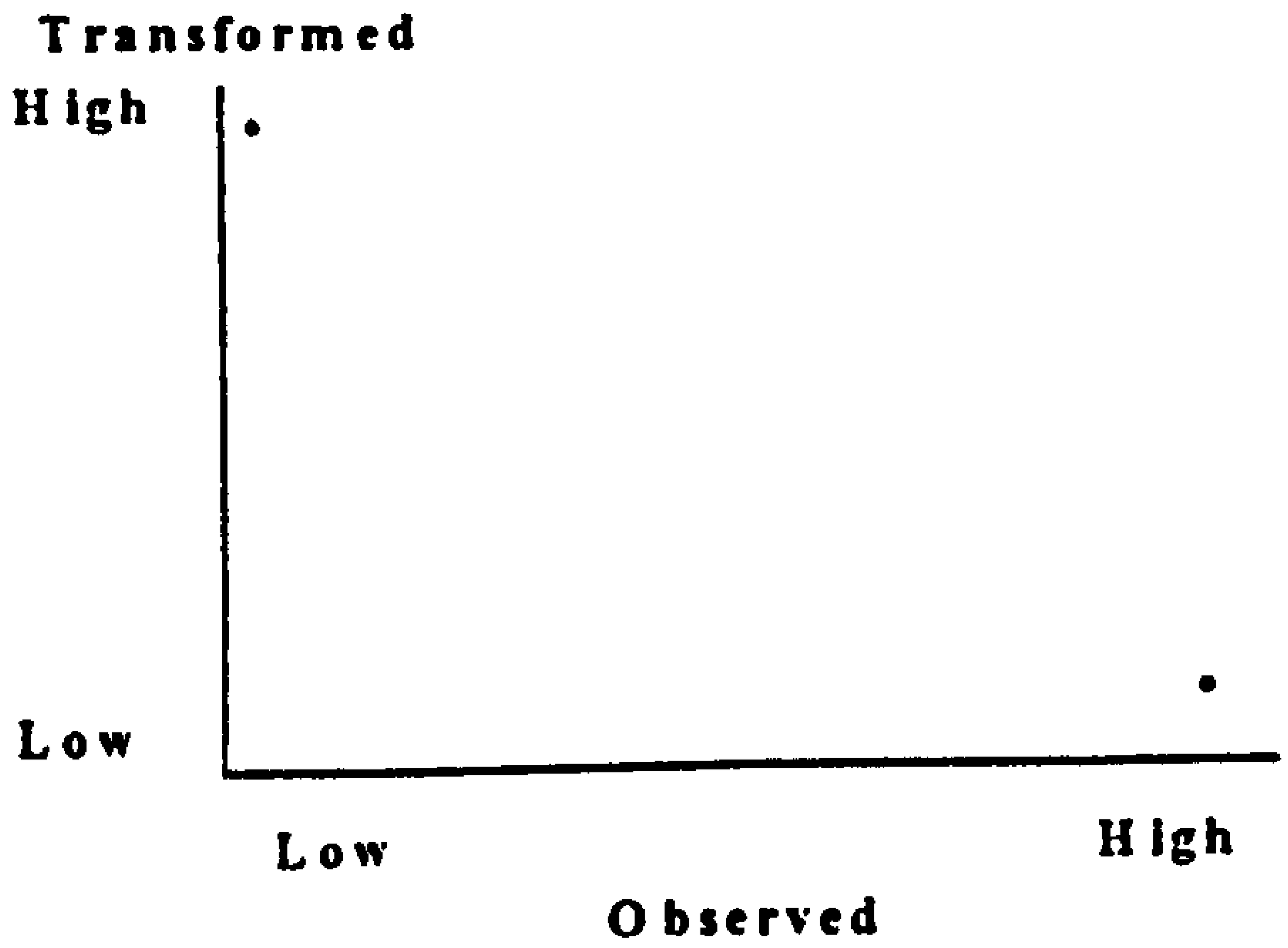
Figure 7. 6 Transformations for Delivery Lead Time



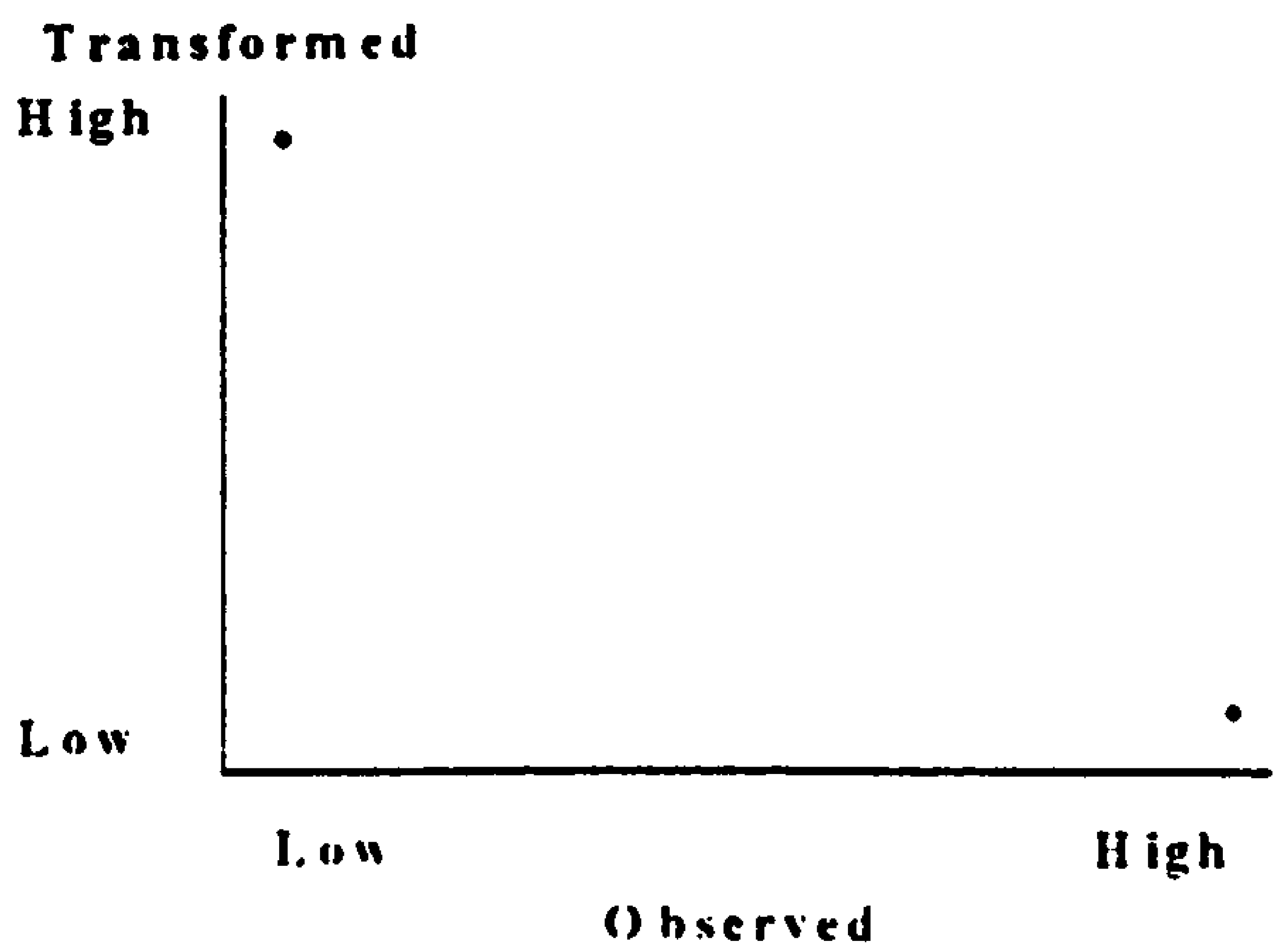
(a) Delivery Lead Time



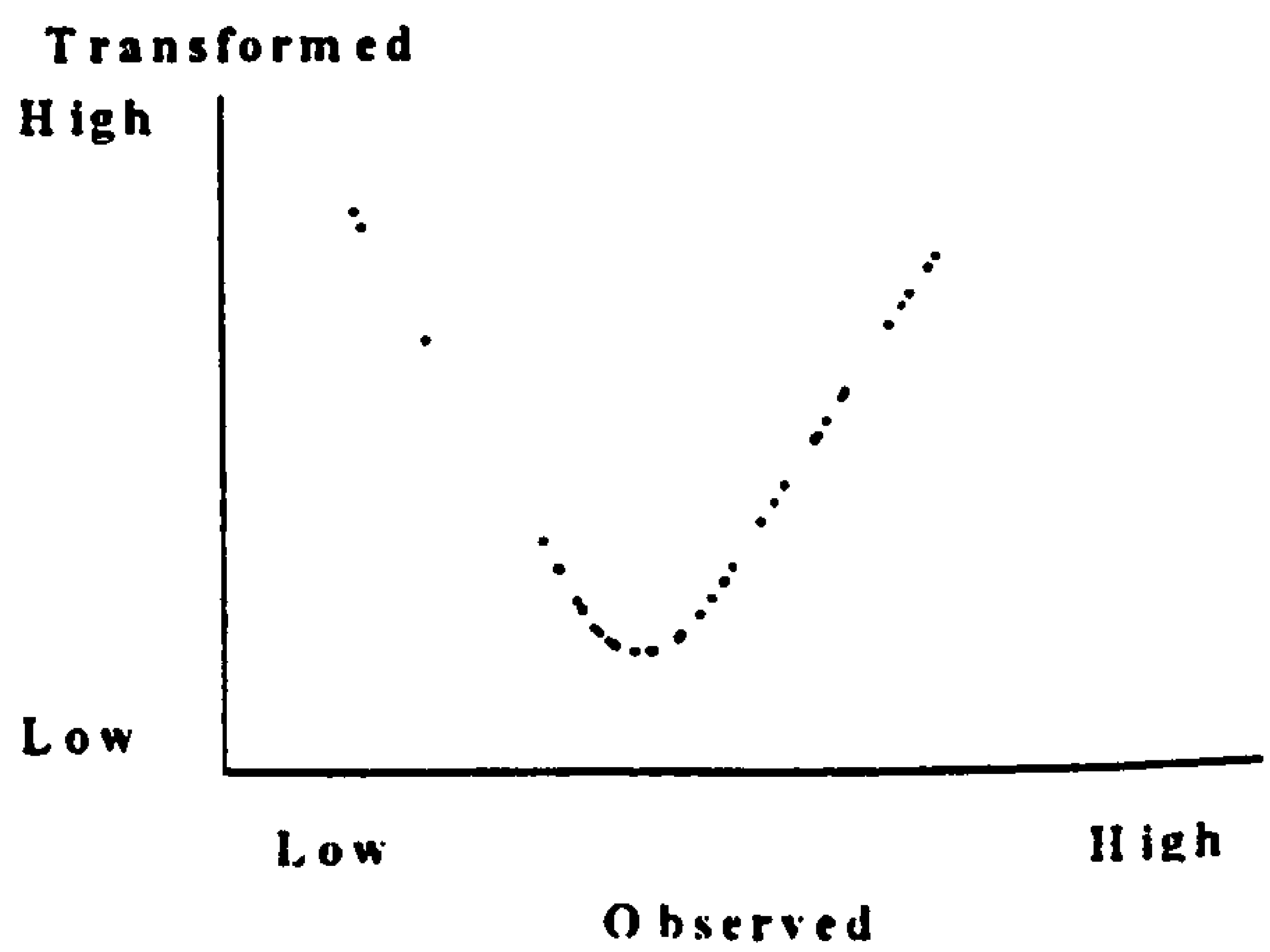
(b) Capacity



(c) Manufacturing Process Dummy V.1



(d) Manufacturing Process Dummy V.2



(e) Supply Planning Data

7.4.4.2 Delivery Lead Time

Table 7.8 shows that capacity constraints uncertainty, manufacturing process and supply planning data accuracy are important determinant variables of delivery lead time. The ACE model of delivery lead time indicate that the previous factors are statistically significant and explained approximately 43.0% of the change in delivery lead time among the Egyptian MRP users.

7.4.4.2.1 The uncertainty of the capacity

The uncertainty of the capacity is a constructed factor comprising capacity constraints and machine downtime (see Figure 7.2). Figure 7.6b suggests that the uncertainty of the capacity leads to the higher delivery lead times. The transformation can be explained as follows: When the capacity constraints and machine downtime are unpredictable, the company's ability to use an MRP system to cut delivery lead times is decreased. This may be because the uncertainty of the capacity may lead to the nervousness in the Master Production Schedule i.e. the MPSs are not held firm by MRP companies, in turn the production can not to meet delivery dates.

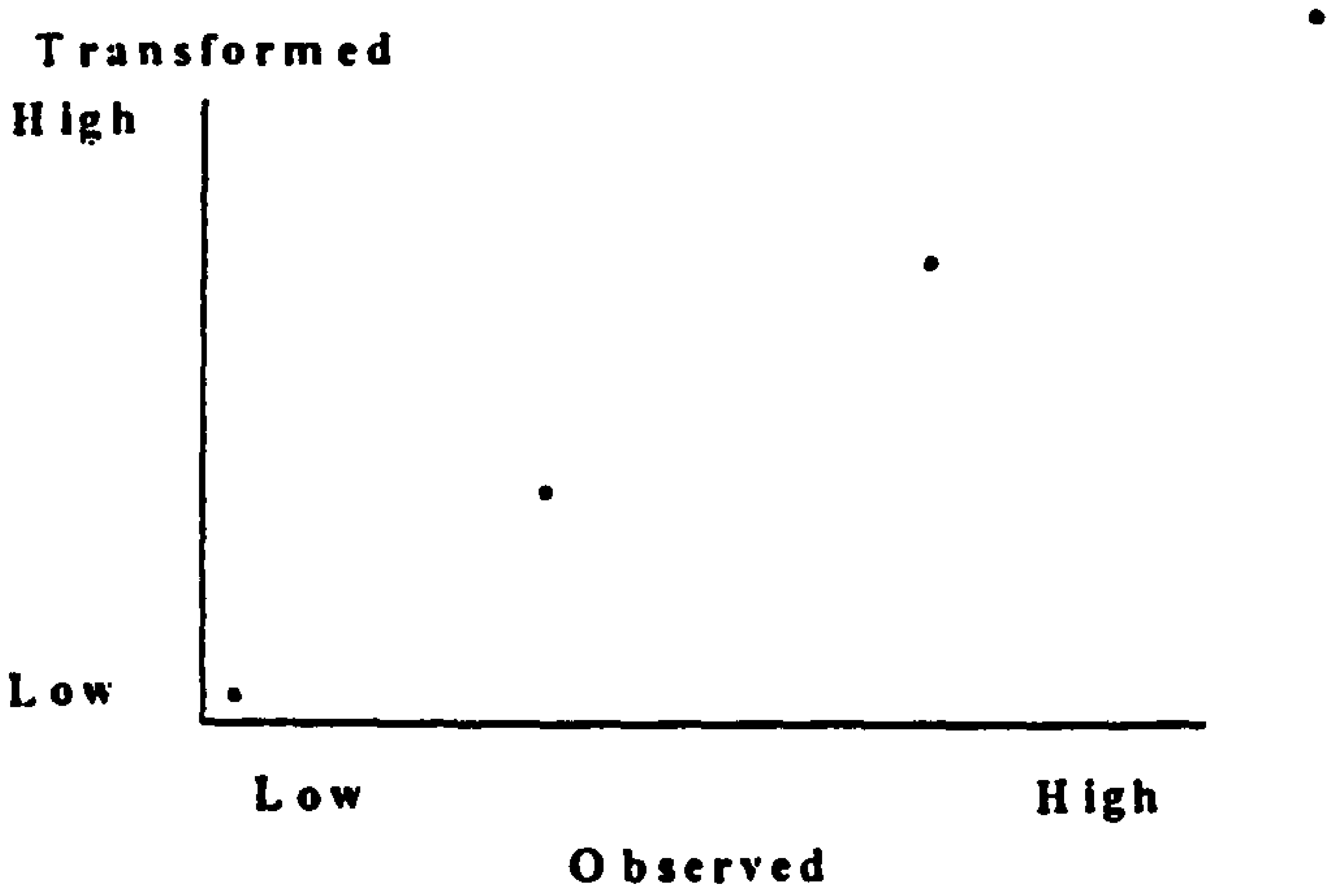
7.4.4.2.2 Manufacturing process

In contrast with Schroeder et al.'s (Schroeder et al., 1981) finding that manufacturing processes do not affect the performance measures, our findings suggest that the continuous industries had lower delivery lead times than the intermittent industries because the nature of this industry helps manufacturing companies to make the customer lead time from order to delivery very low. The investigation of the difference in the parameter estimates between continuous and intermittent industries variables (Table 7.8) is .0048 in support of the continuous industry.

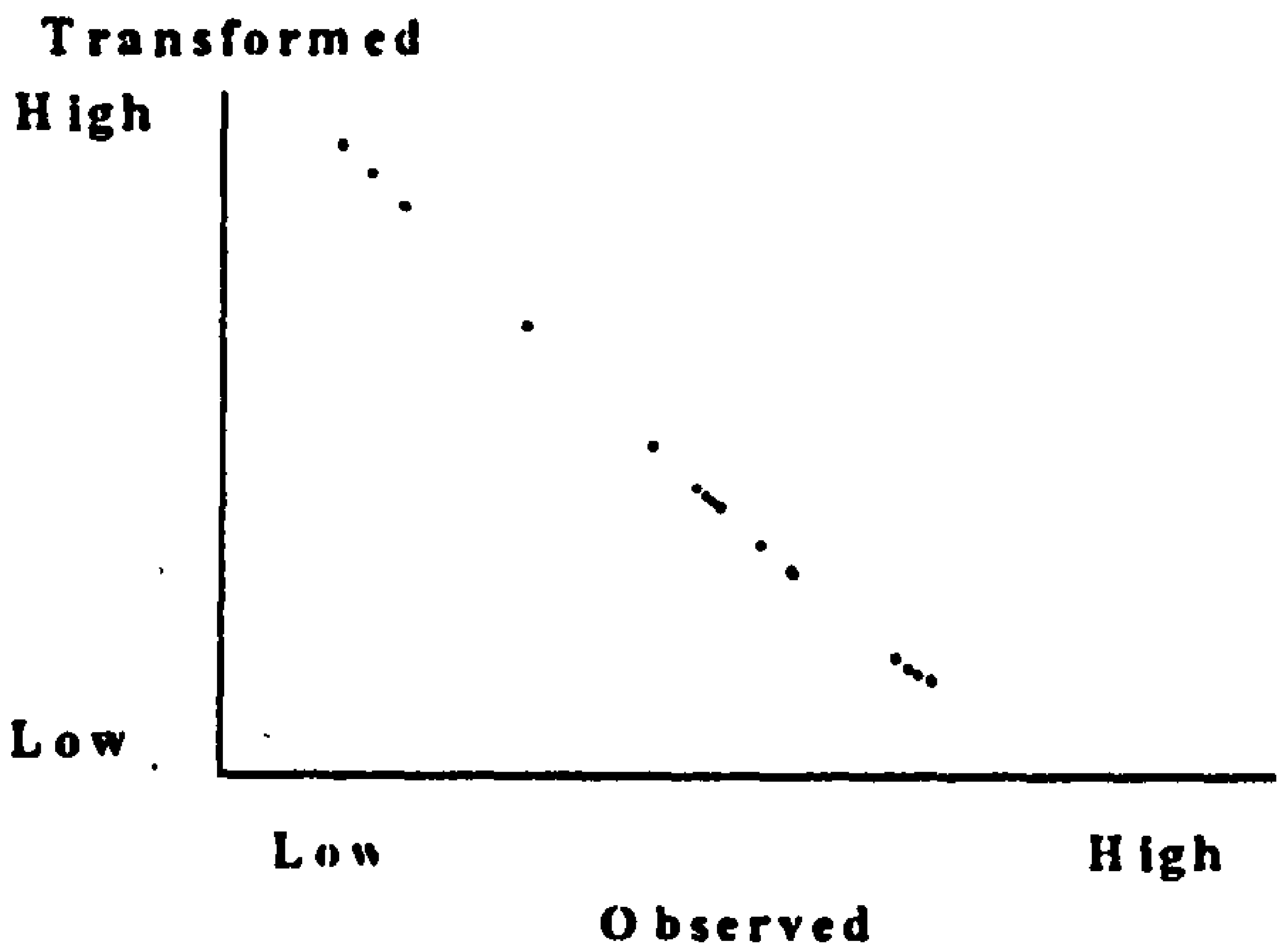
7.4.4.2.3 Supply planning data

The non-linear transformation in Figure 7.6e indicates that there is a turning point for the impact of supply planning data which comprises capacity data, vendor lead times and production lead times on the delivery lead time. This shows that the increase of supply data planning led to a decrease followed by an increase in delivery lead time. Our insight into this is built upcn the fact that the data extracted from the system does not continue to be accurate all times, but it may become inaccurate when users refuse to follow the recommendations produced by the system anymore (Sum et al., 1995). Subsequently any decision or process built upon these data such as determining delivery lead time is improper.

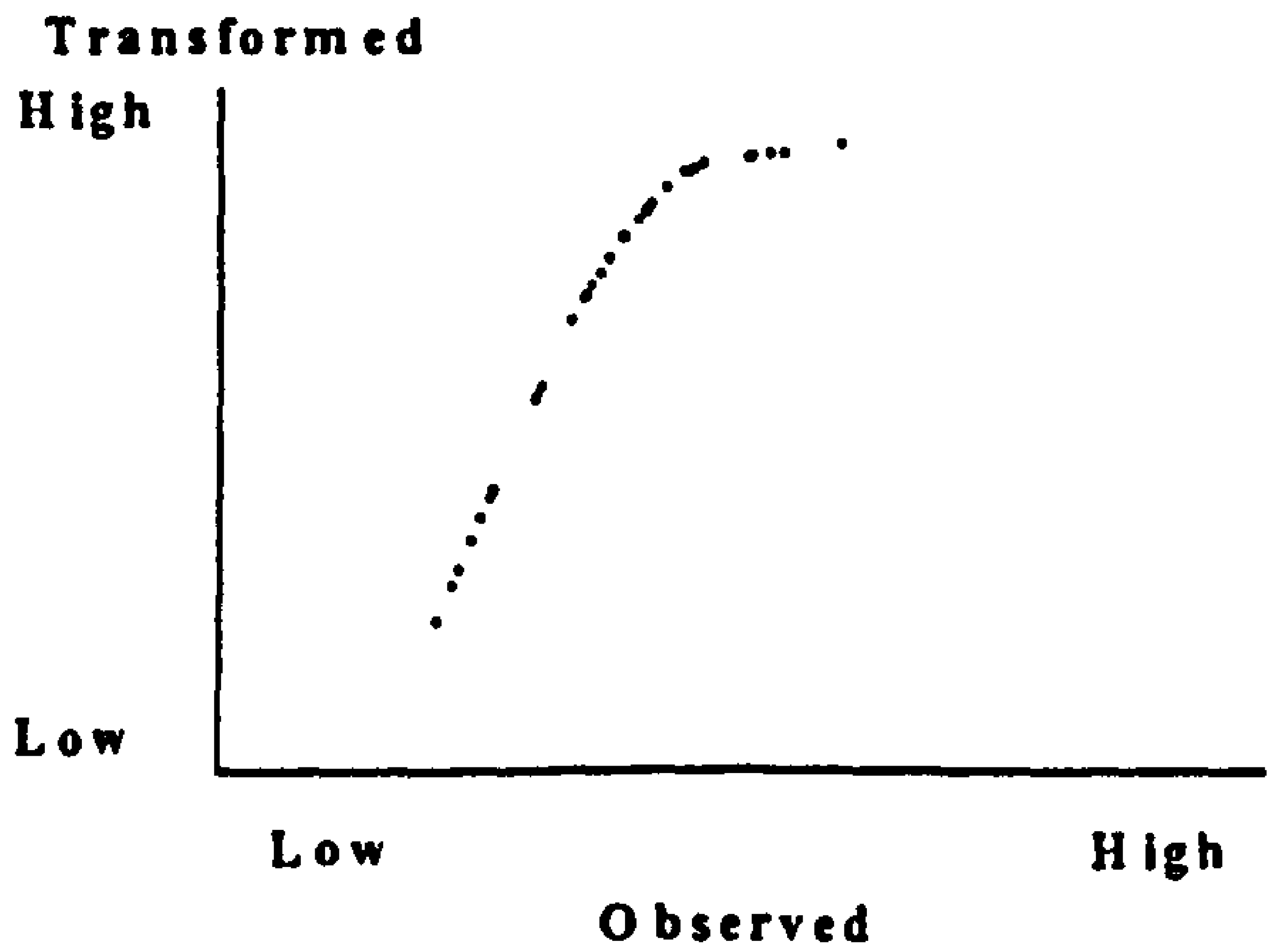
Figure 7.7 Transformations for Percent of Delivery Promises



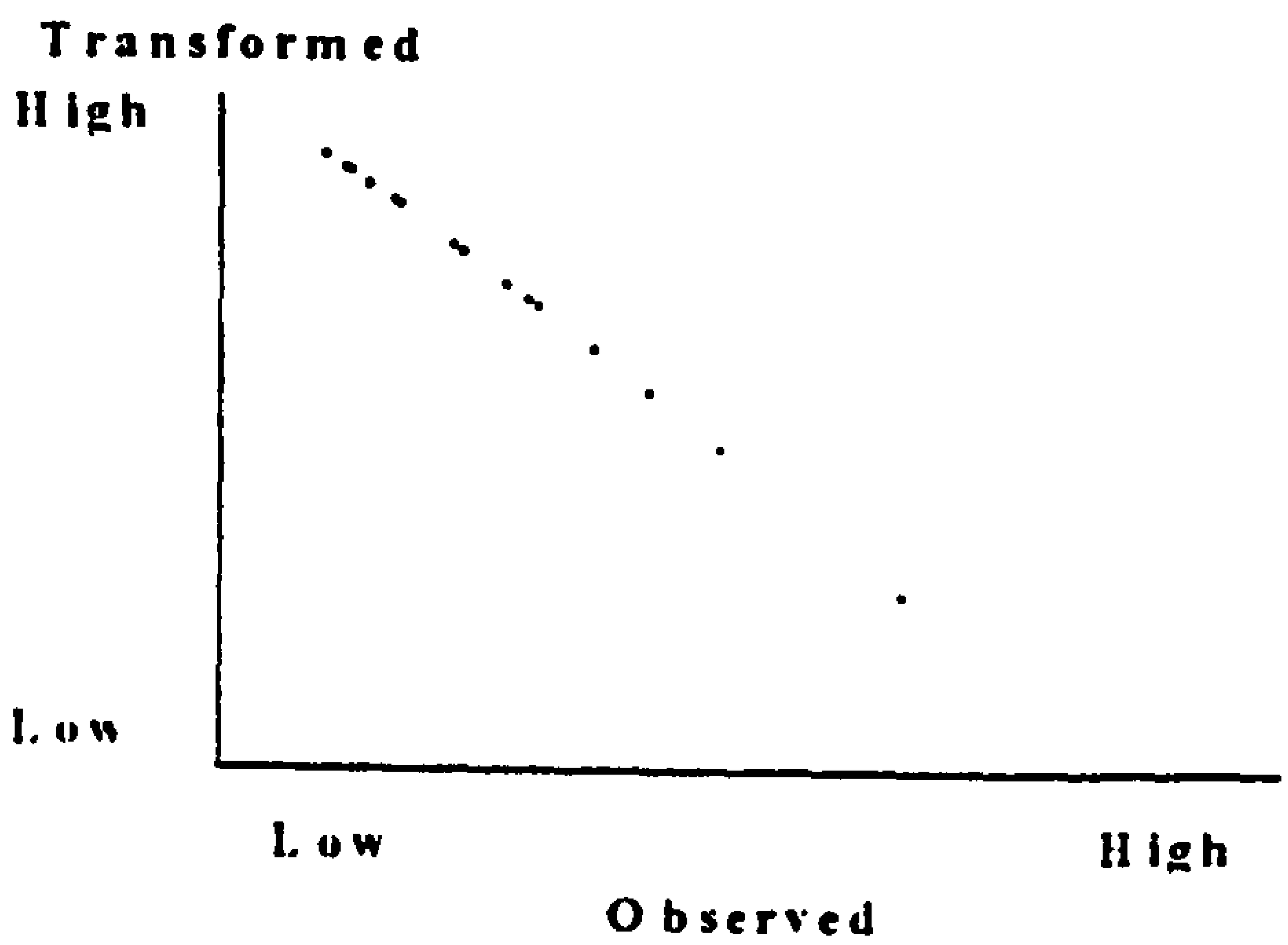
(a) Delivery Promises



(b) Reliability



(C) Schedule Execution Data



(d) People Support Problem

7.4.4.3 Percent of Time Meeting Delivery Promises

The company's ability to meet delivery promises is affected by the degree of uncertainty of the reliability, schedule execution data and people support problems (Table 7.8). The variable transformations are depicted in Figure 7.7.

7.4.4.3.1 The uncertainty of the reliability

Reliability is a constructed factor comprising behaviour of people and reliability of plant within the factory (Figure 7.2). Figure 7.7b suggests that manufacturing companies with more unreliable behaviour of people and plant within the factory wall had lower percent of time meeting delivery promises. This result concurs with the notion that in order to achieve the successful implementation (the higher performance) the company must integrate the system with daily operations (Duchessi et al., 1989) and which, often, are based on work force planning and master production scheduling.

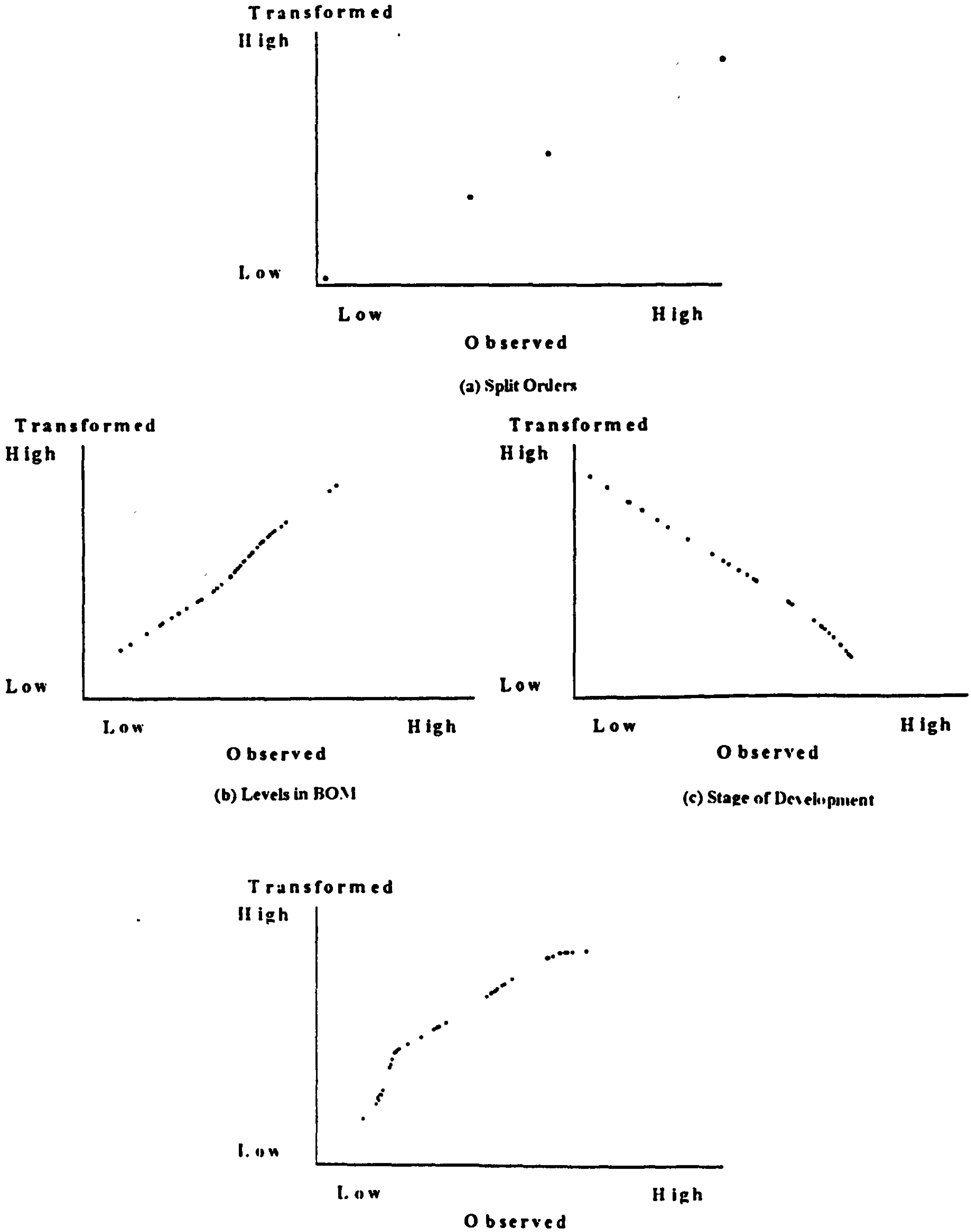
7.4.4.3.2 Schedule execution data

As mentioned in Dilworth (1993); ElKhouly (1994) and Browne et al. (1996), data accuracy has a positive effect on MRP implementation. Figure 7.7c shows that schedule execution data accuracy has a positive impact on meeting delivery promises. This could be explained by the realistic master schedule as a result of data accuracy usage. This result supports Schroeder et al.'s (Schroeder et al., 1981) and Sum et al.'s (Sum et al., 1995) findings that data accuracy affects delivery promises.

7.4.4.3.3 People support problem

The descent trend in Figure 7.7d indicated that people support problem reduces the percent of meeting delivery promises. This supports the notion that higher performance such as higher meeting delivery promises is accompanied by higher people support (Turnipseed et al., 1992; Dilworth, 1993). This result concurs with Schroeder et al.'s (Schroeder et al., 1981) finding that delivery promises is affected by people support.

Figure 7. 8 Transformations for Percent of Split Orders



(a) Split Orders

(b) Levels in BOM

(c) Stage of Development

(d) Management Support Problem

7.4.4.4 Percent of Split Orders

Table 7.8 shows that three independent variables have a significant impact on the percent of spilt orders, they are levels in BOM, stage of development and management support problem respectively.

7.4.4.4.1 Levels in BOM

The levels in BOM transformation displayed in Figure 7.8b indicates that increasing levels in bill of materials has a positive impact on the percent of spilt orders. The explanation can be offered for that effect is derived from the fact that a complex BOM is a potential source of inefficiency for a production planning and control system (Etienne, 1983; Sum et al., 1995). This may be reflected in increasing the percent of split orders because of unavailable material as was demonstrated by (Schroeder et al., 1981).

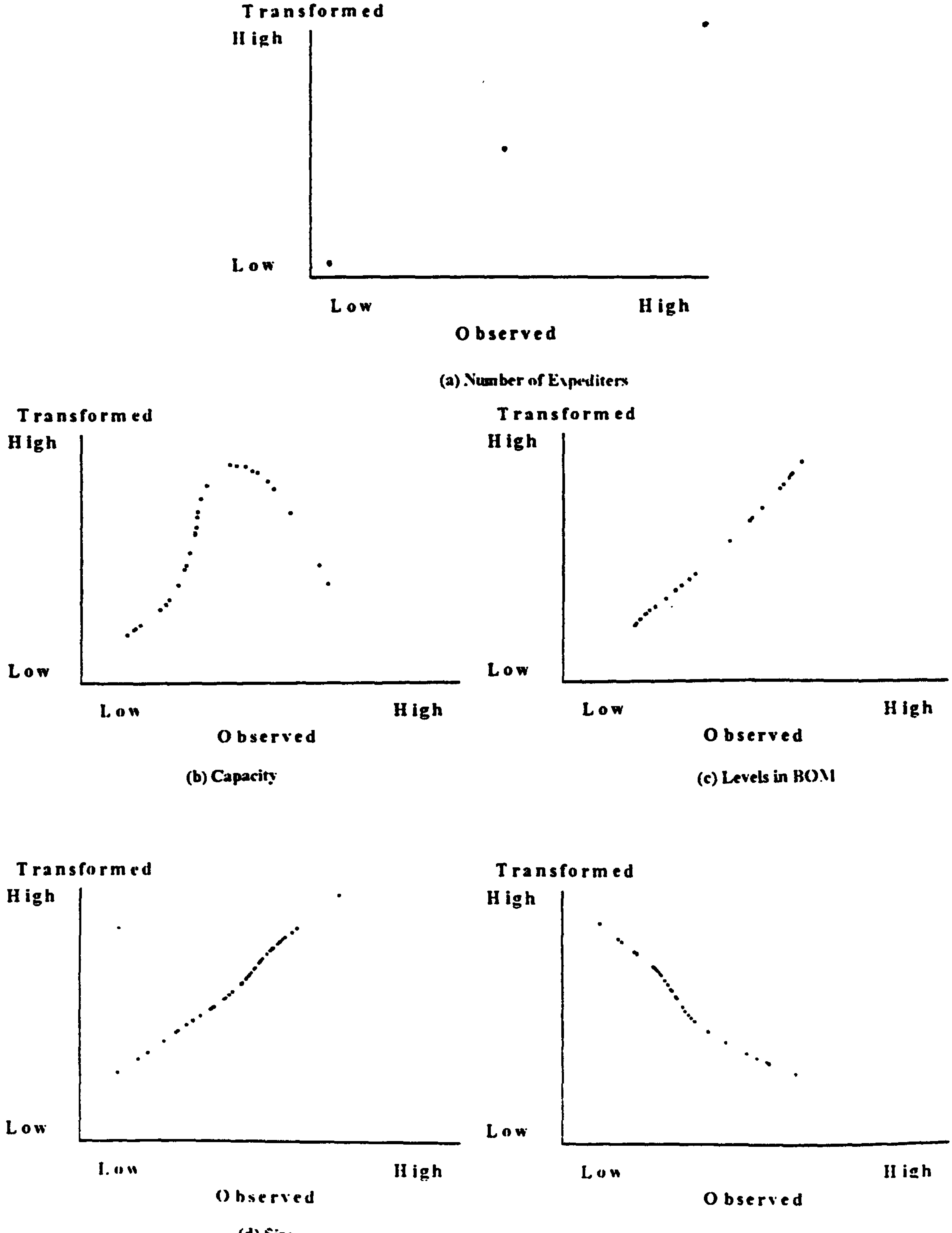
7.4.4.4.2 Stage of development

As shown in Figure 7.8c there is a negative relationship between the stage of MRP implementation and the percent of split orders. As the stage of MRP implementation increases, the percent of split orders decreases because of unavailable material. This concurs with the notion that when companies adopt an advanced stage of MRP system (i.e. Classes B & A) the accuracy and stability of master production schedule will increase. As a consequence, the degree of accuracy of BOM also will be increased. This result supports Schroeder et al.'s (Schroeder et al., 1981) finding that the percent of split orders is adversely affected by the stage of MRP implementation.

7.4.4.4.3 Management support problem

The upward trend in Figure 7.8d supports the notion that higher performance is accompanied by higher top management support. The transformation for top management support problem in Figure 7.8d suggests that where little problem with management support was encountered, companies had a lower percent of split orders. This result affirms the importance of top management support for improving the operational use and improving performance (Duchessi et al., 1989) and also, conforms with the findings of Schroeder et al. (1981).

Figure 7. 9 Transformations for Number of Expediters



(a) Number of Expediters

(b) Capacity

(c) Levels in BOM

(d) Size

(e) Stage of Development

7.4.4.5 Number of Expediters

The ACE model for number of expediters (Table 7.8) indicates that the uncertainty of the capacity, levels in BOM, company size and stage of MRP implementation variables had explained approximately 45.0% of changes of the number of expediters among the Egyptian users.

7.4.4.5.1 The uncertainty of the capacity

The transformation for the uncertainty of the capacity in Figure 7.9b suggests that as the capacity is unpredictable the number of expediters increases and then decreases. When little unpredictable of capacity is encountered, companies had lower number of expediters because there is little falling behind with schedules, but at the turning point the position is totally different where the increase of the uncertainty of the capacity is adversely related to the number of expediters. This could be due to the company depending on *ad hoc* solutions, such as supply from an alternative source (Per-lind, 1991).

7.4.4.5.2 Levels in BOM

The number of expediters is adversely affected by the number of levels in BOM. Figure 7.9c suggests that as the levels of bill of materials increase the number of expediters is likely to be increased. This is expected because increasing levels in BOM may lead to an increase in materials, subassemblies, and parts behind schedule. This means that a company may need to increase the number of expediters in order to meet customers needs in the due dates.

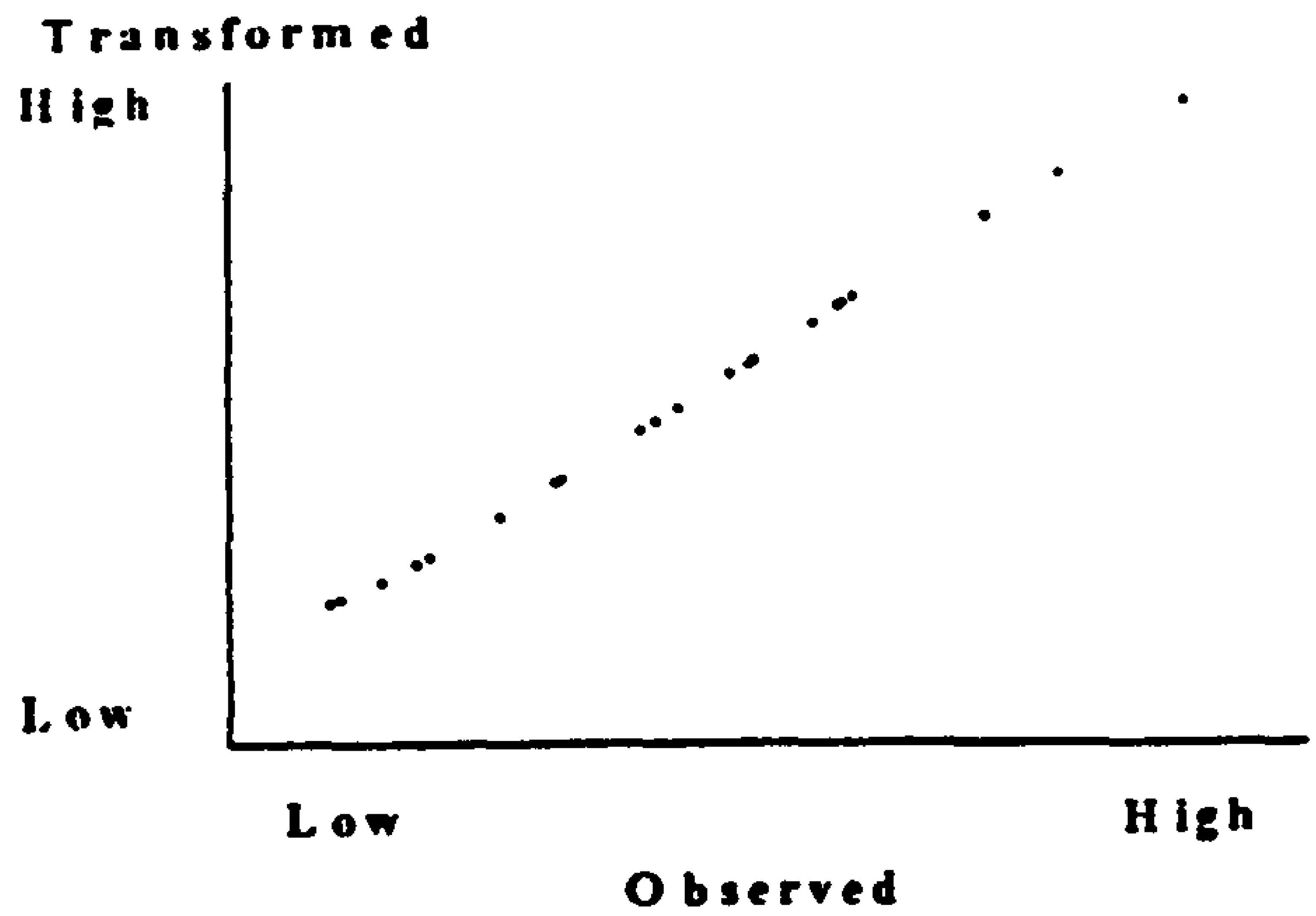
7.4.4.5.3 Company size

Figure 7.9d suggests that increasing company size has a positive impact on the number of expediters. Since company size is related to the scale and scope of the manufacturing operations (Sum et al., 1995), therefore the large companies are likely to have more hot jobs and more behind schedule, which may lead to the need to more expediters in order to reduce the deviations between two dates (due date and need date), namely making the two dates coincided (Plossl, 1995). This supports the findings of Schroeder et al. (1981).

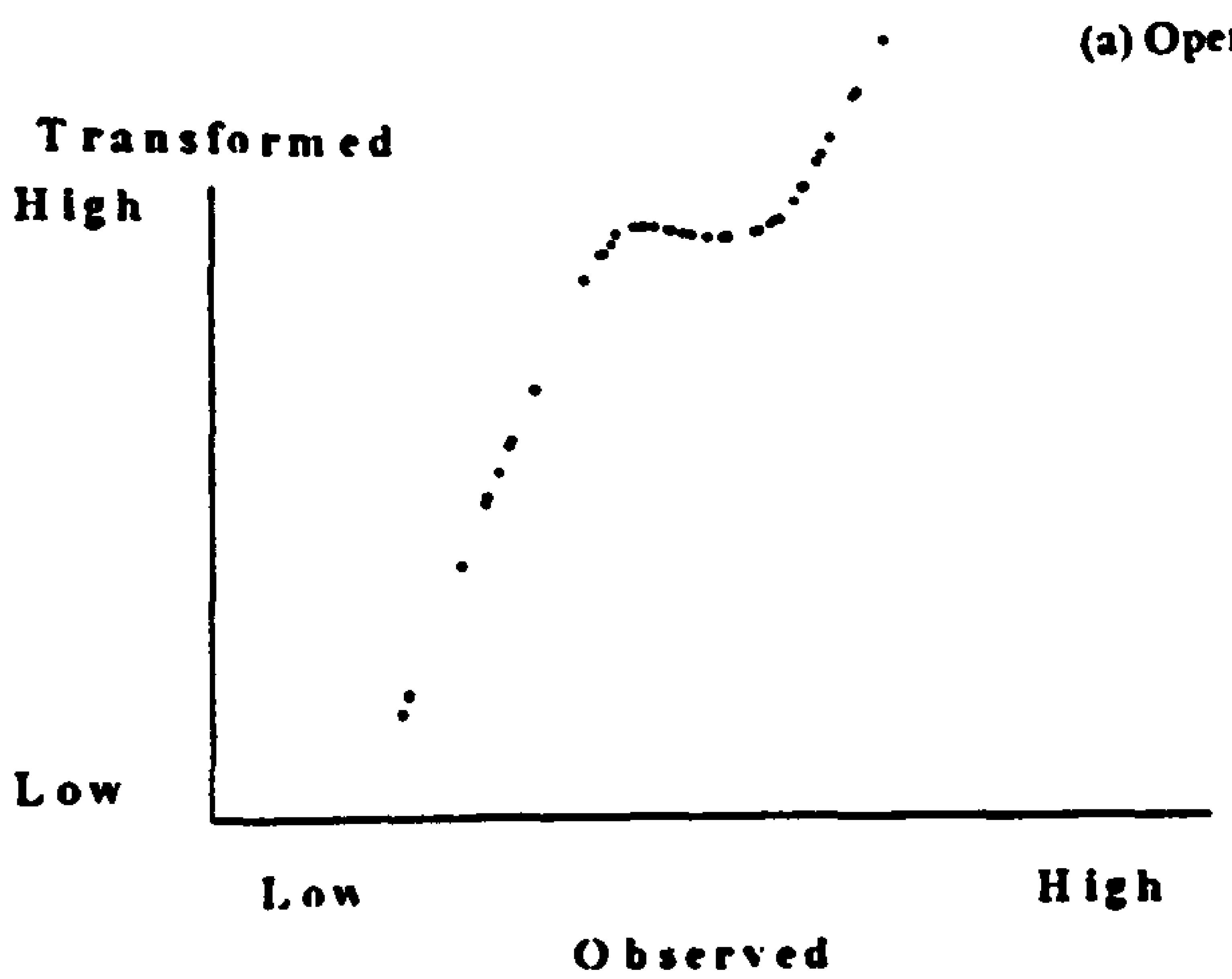
7.4.4.5.4 Stage of development

Table 7.8 affirms the importance of the stage of development in increasing performance. Figure 7.9e suggests that as the stage of development increases, the growing computerisation in all MRP modules such as inventory control, bill of materials and master production schedule increases, and this will be reflected in minimising behind schedule (Mady, 1992), namely, minimising the number of expediters. This result supports Schroeder et al. 's (Schroeder et al., 1981) finding that the number of expediters is adversely affected by the stage of MRP implementation.

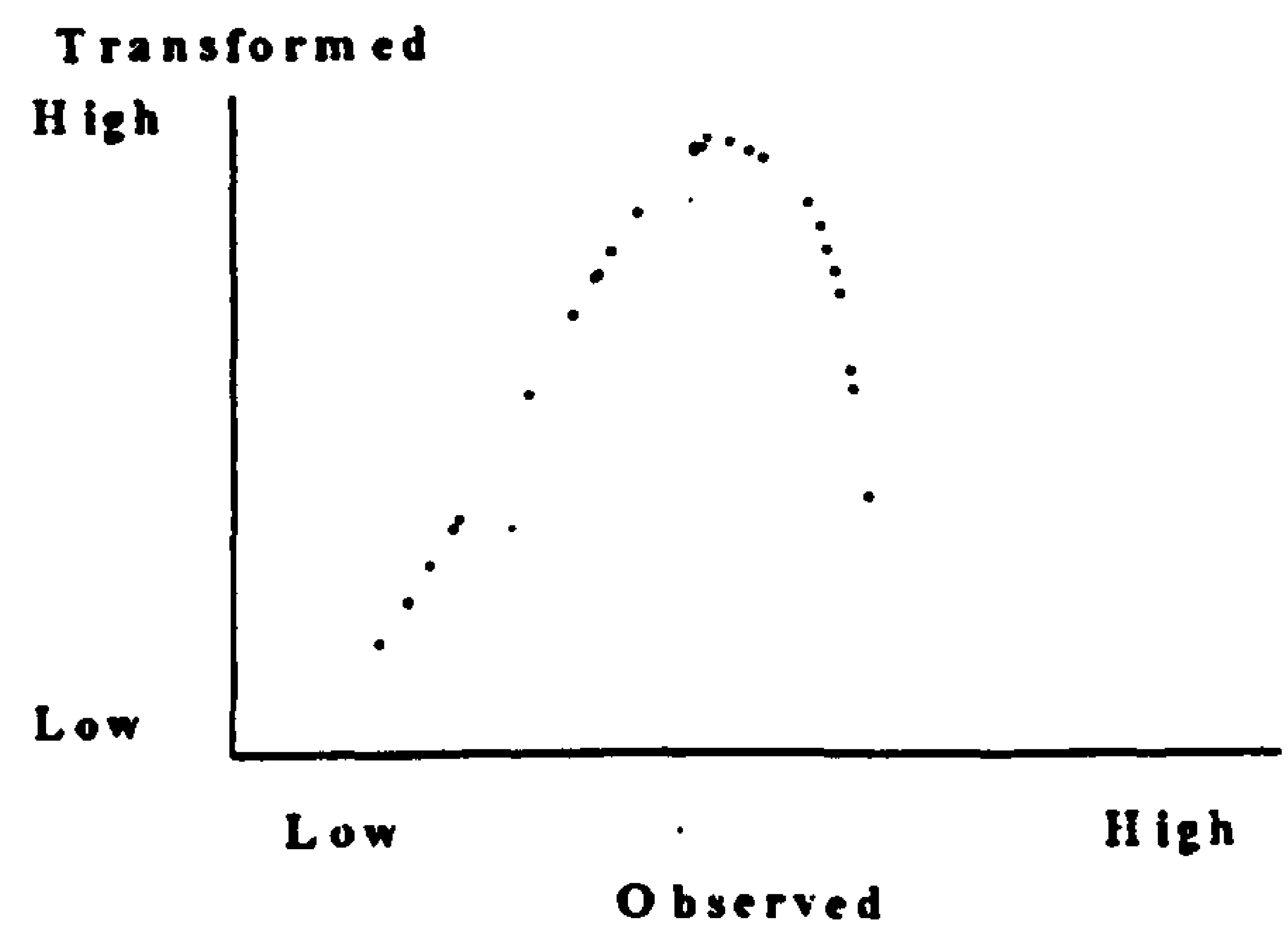
Figure 7. 10 Transformations for Operational Efficiency



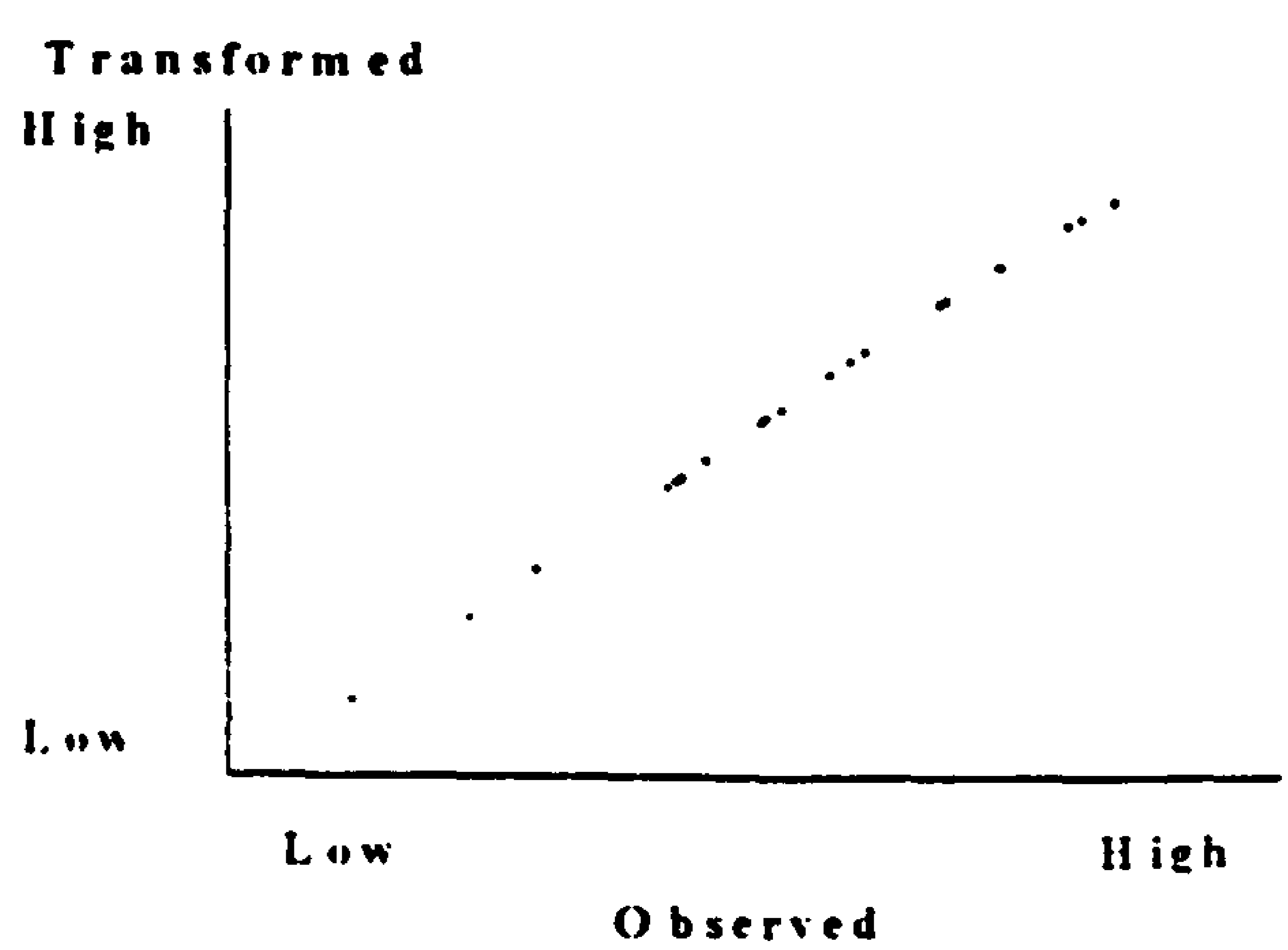
(a) Operational Efficiency



(b) Size



(c) Stage of Development



(d) Operating Execution Data

7.4.4.6 Operational Efficiency

Table 7.8 shows that operational efficiency (increased throughput and improved product quality) is affected by company size, the stage of development and operating execution data accuracy.

7.4.4.6.1 Company size

The size transformation displayed in Figure 7.10b indicates that increasing company size has a positive followed by "plateau" then positive impact again on efficiency. The first part of the curve indicates that as company size increases the growing ability to increase throughput and improve product quality tends to be increased. The plateau stage can be explained in the light of the fact that as size gets too big, the conflicting technologies, objectives, processes, and procedures might set in (Sum et al., 1995). Consequently, further benefits have not been reaped, in turn companies try to keep on the existing level of benefits achieved. But this is inconsistent with Sum et al.'s (Sum et al., 1995) finding that increasing size has a positive followed by a negative impact on efficiency. They stated that as size increases, diseconomies and inefficiencies due to conflicting technologies, objectives, processes and procedures might set in.

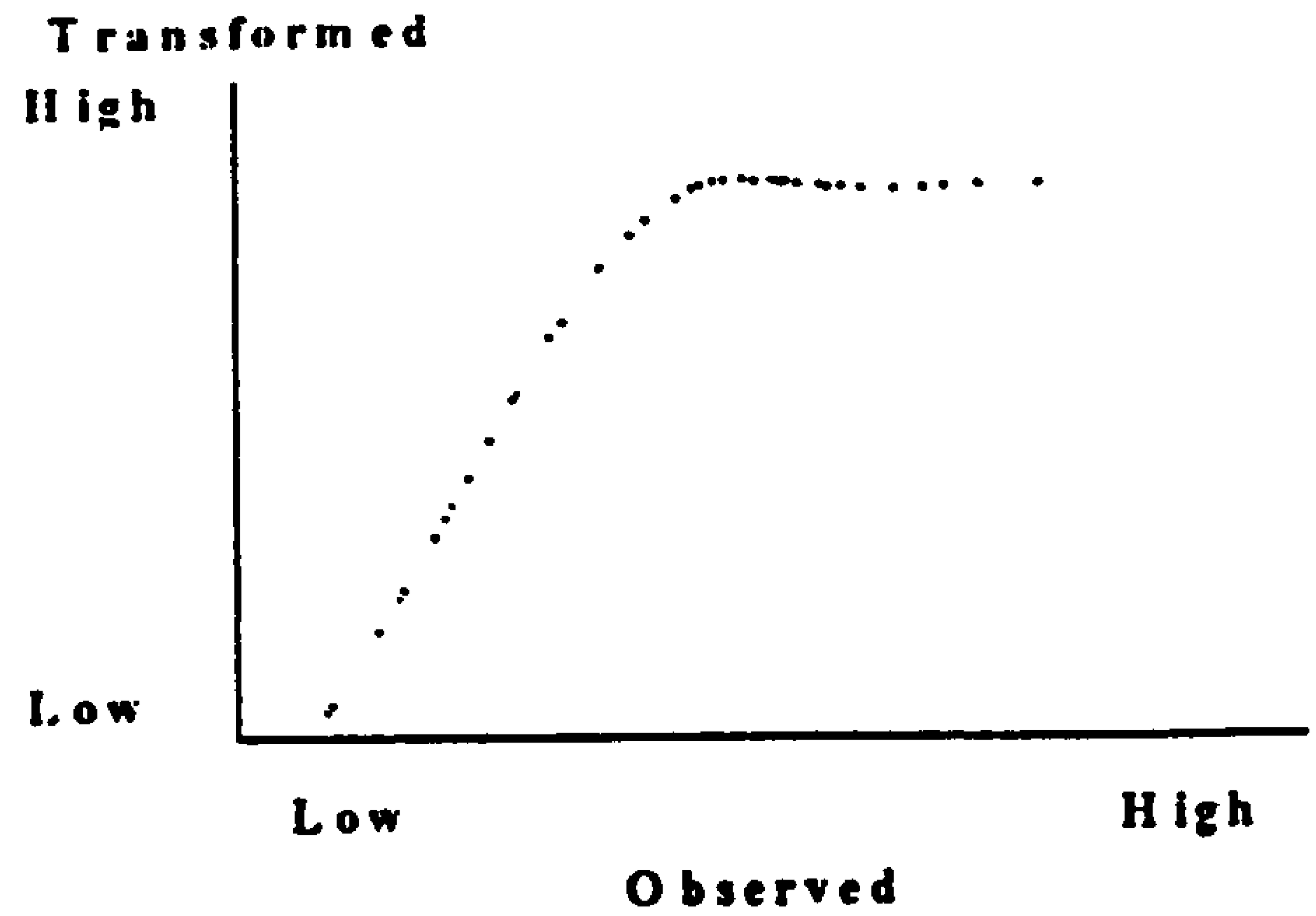
7.4.4.6.2 Stage of MRP implementation

Figure 7.10c reveals that increasing stage of development has a positive followed by a negative impact on efficiency. Our insight into the turning point phenomena in Figure 7.10c is derived from the fact that increasing stage of MRP implementation means that company tends to develop the formal system of planning and control by increasing formal policies, procedures and responsibilities (Duchessi et al., 1989), and which may lead to more resistance or more conflict from people part within a factory.

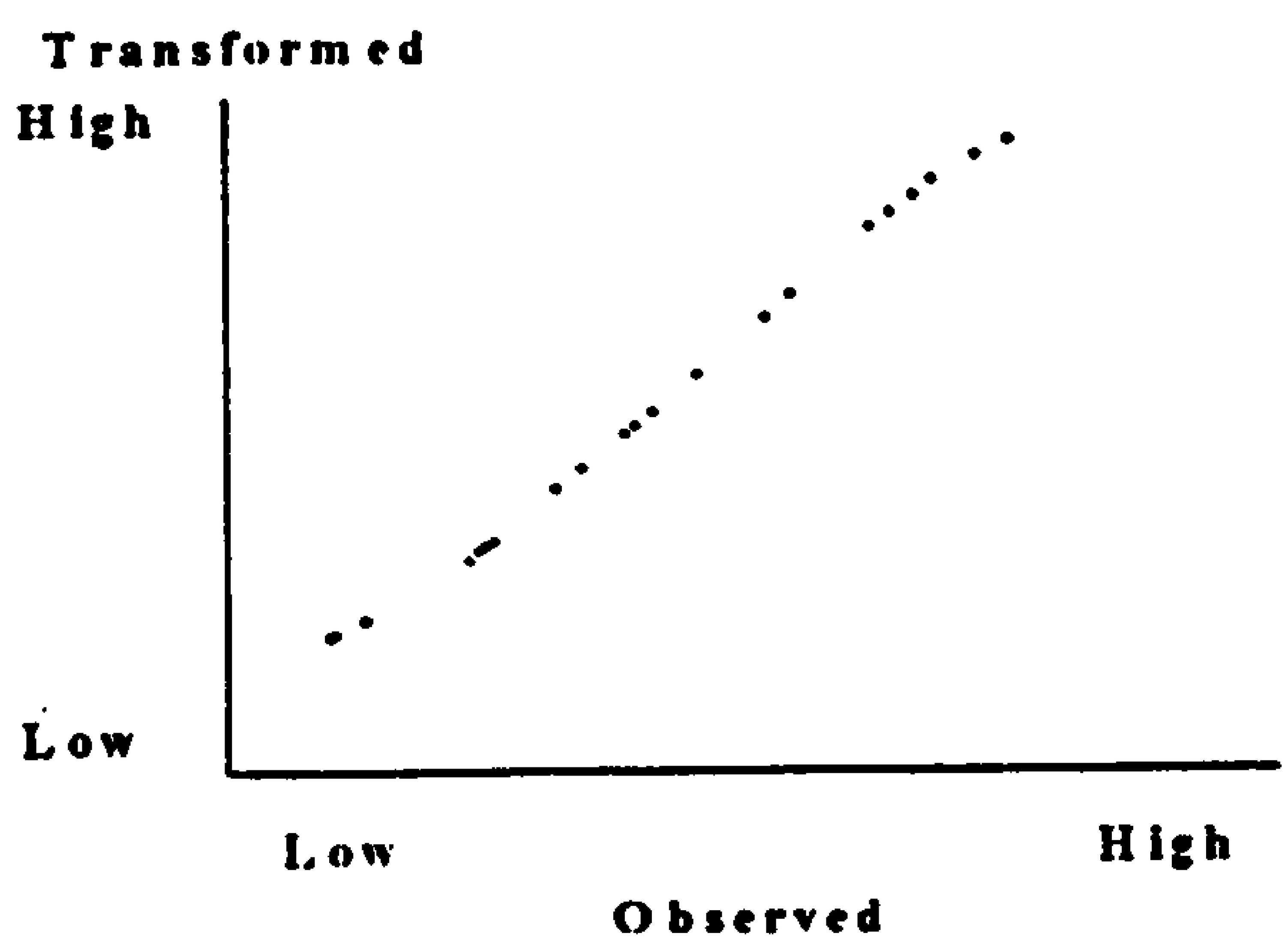
7.4.4.6.3 Operating execution data

The transformation for the operating execution data accuracy in Figure 7.10d is similar to Figure 7.7c in that high data accuracy is needed to achieve both the tangible and subjective benefits. An explanation could be that operational efficiency requires accurate data about planning data (capacity, vendor lead times, production lead times) and execution data (shop floor control). Thus, data accuracy can be considered as a major determinant variable of the successful implementation (Duchessi et al., 1989).

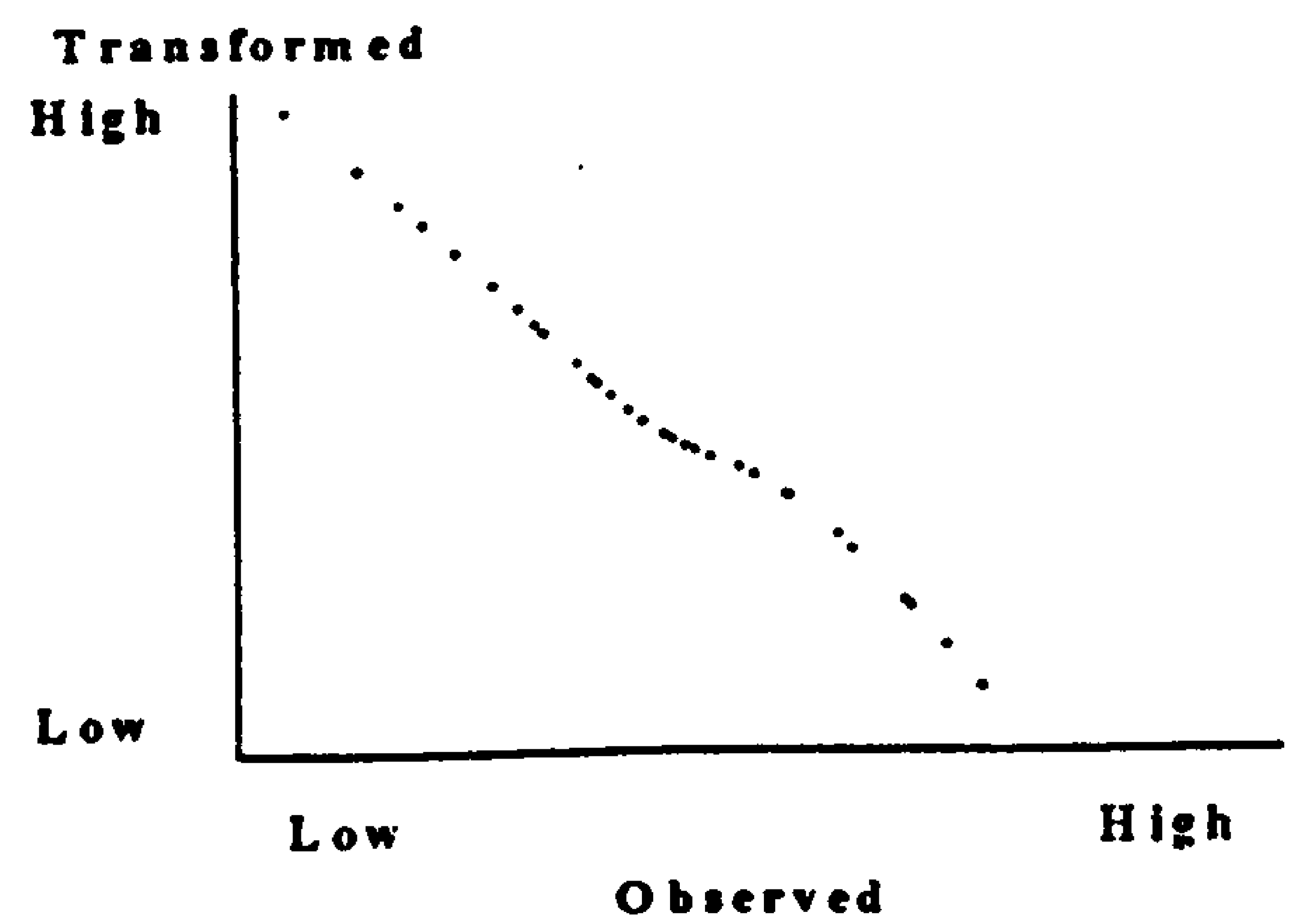
Figure 7. 11 Transformations for Co-ordination



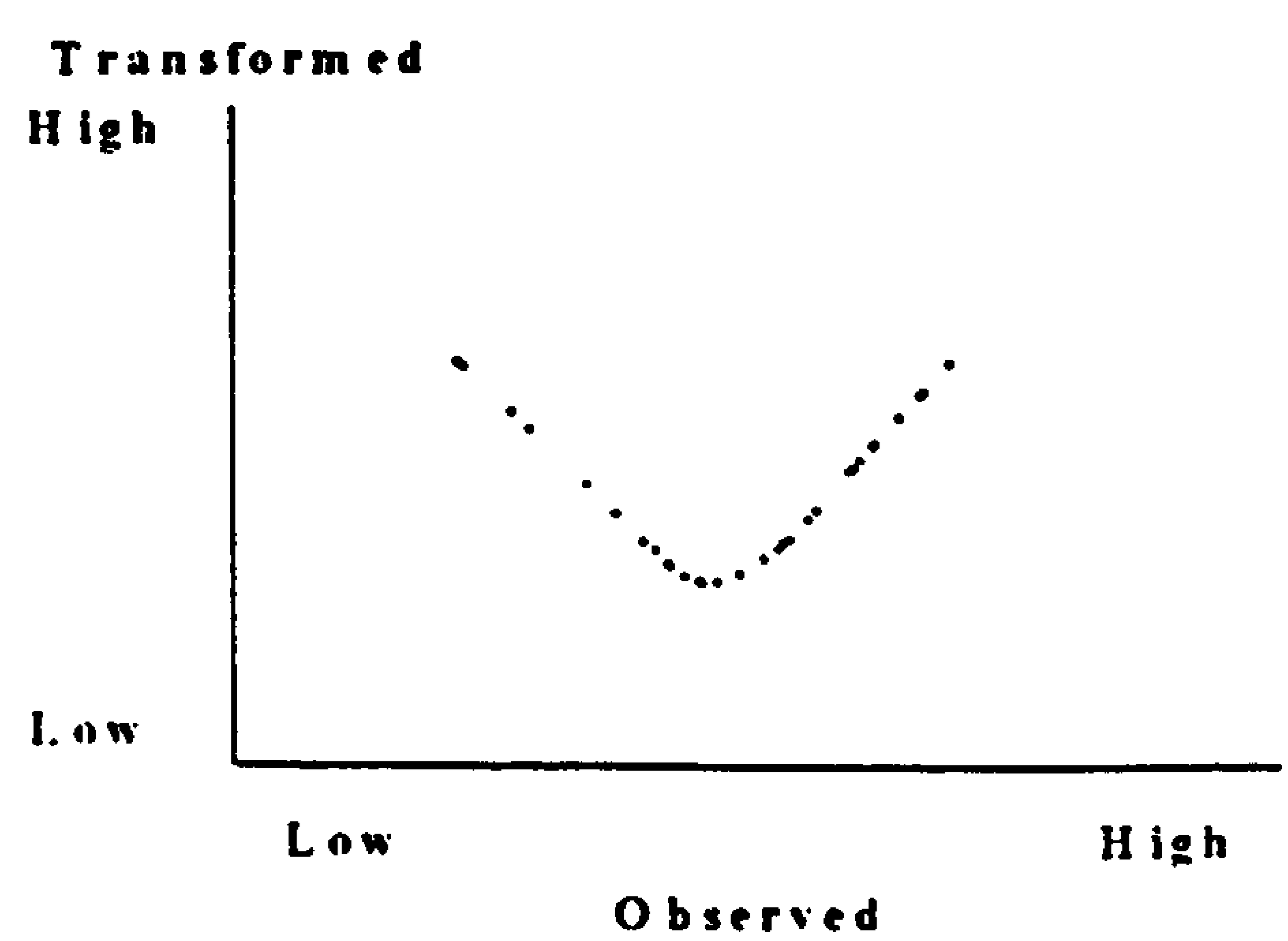
(a) Co-ordination



(b) Demand Planning Data



(c) Management Support Problem



(d) People Support Problem

7.4.4.7 Co-ordination

The ACE model for co-ordination benefit reveals that demand planning data, management support problem and people support problem are statistically significant independent variables affecting co-ordination among operations, marketing and finance. The variable transformations are displayed in Figure 7.11.

7.4.4.7.1 Demand planning data

The upward trend in Figure 7.11b supports the fact that the higher co-ordination among functions and sub-systems within the organisation is accompanied by higher quality of data flow across them (Sum et al., 1995). Figure 7.11b suggests data accuracy is important for effective co-ordination.

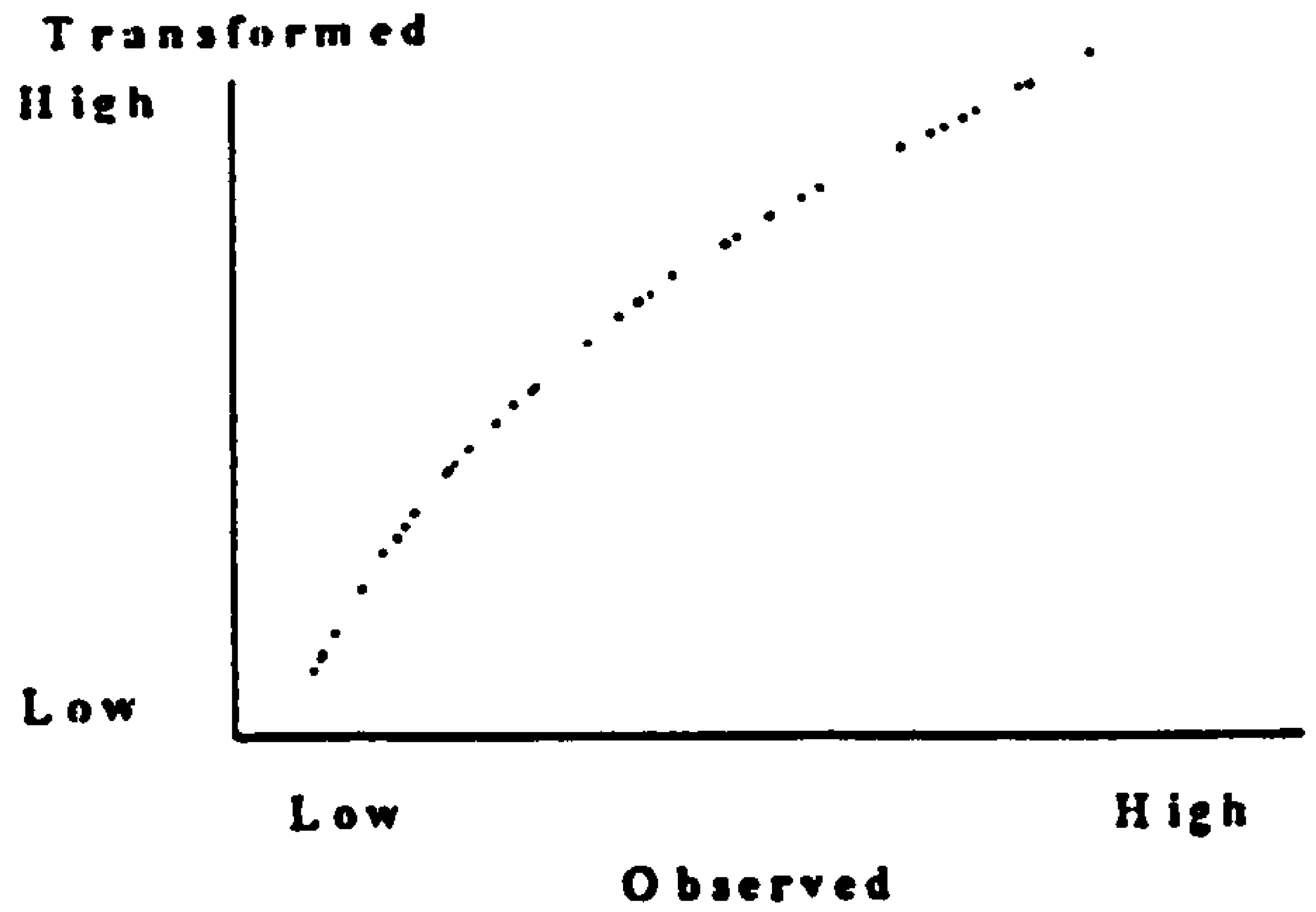
7.4.4.7.2 Management support problem

Figure 7.11c suggests that increasing management support problem has a negative impact on co-ordination. An explanation could be that effective co-ordination requires management support to set clear goals for the implementation and to distribute responsibilities across functional areas (Duchessi et al., 1989).

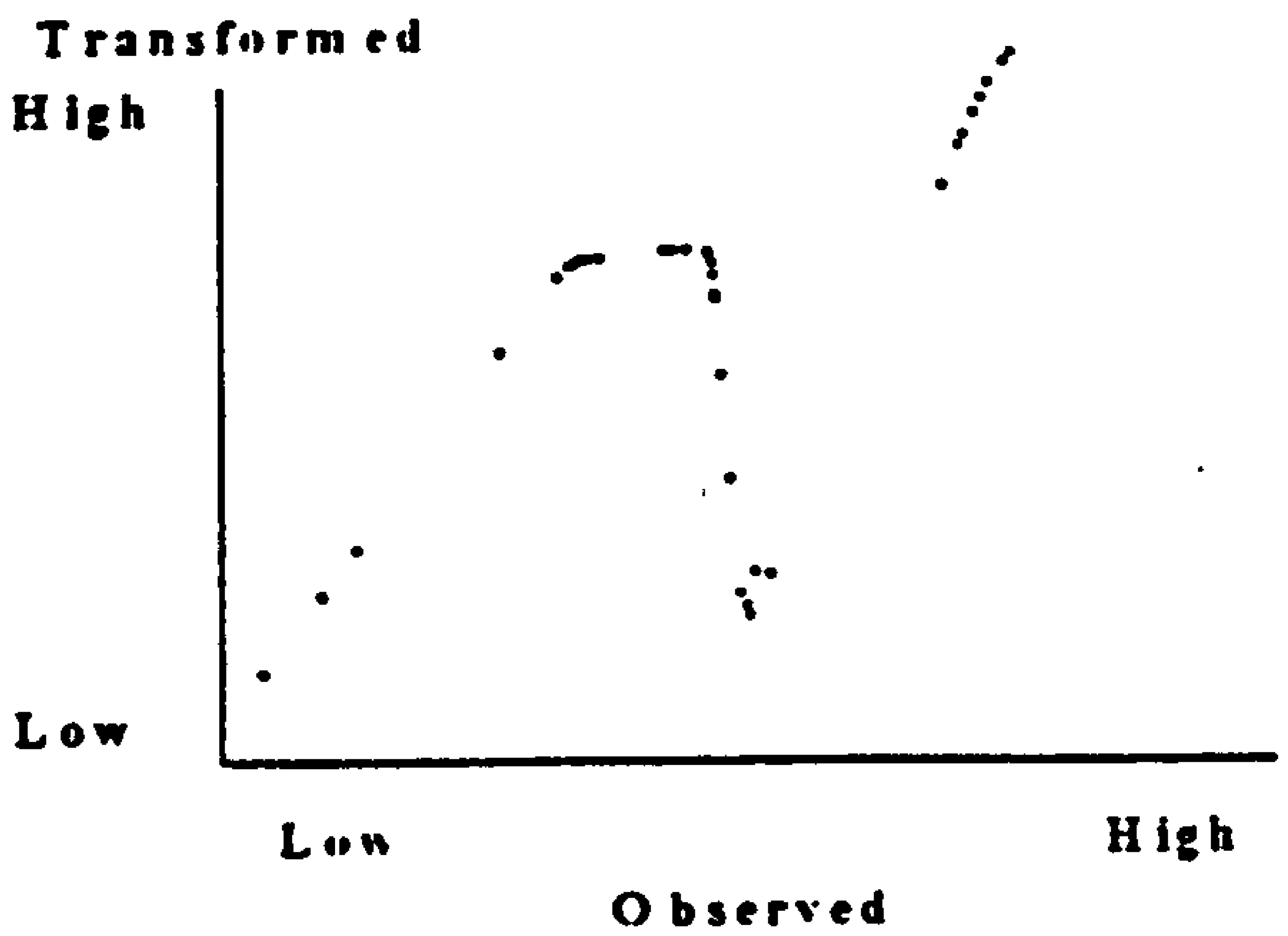
7.4.4.7.3 People support problem

The transformation in Figure 7.11d reveals that people support problems such as lack of support from supervisor/foreman and lack of company expertise in MRP reduce co-ordination. This is expected since the implementation of any new formal systems is accompanied with resistance or lack of knowledge about it across departments. This result to a great degree concurs with Sum et al.'s (Sum et al., 1995) finding that increasing people support problems reduce co-ordination.

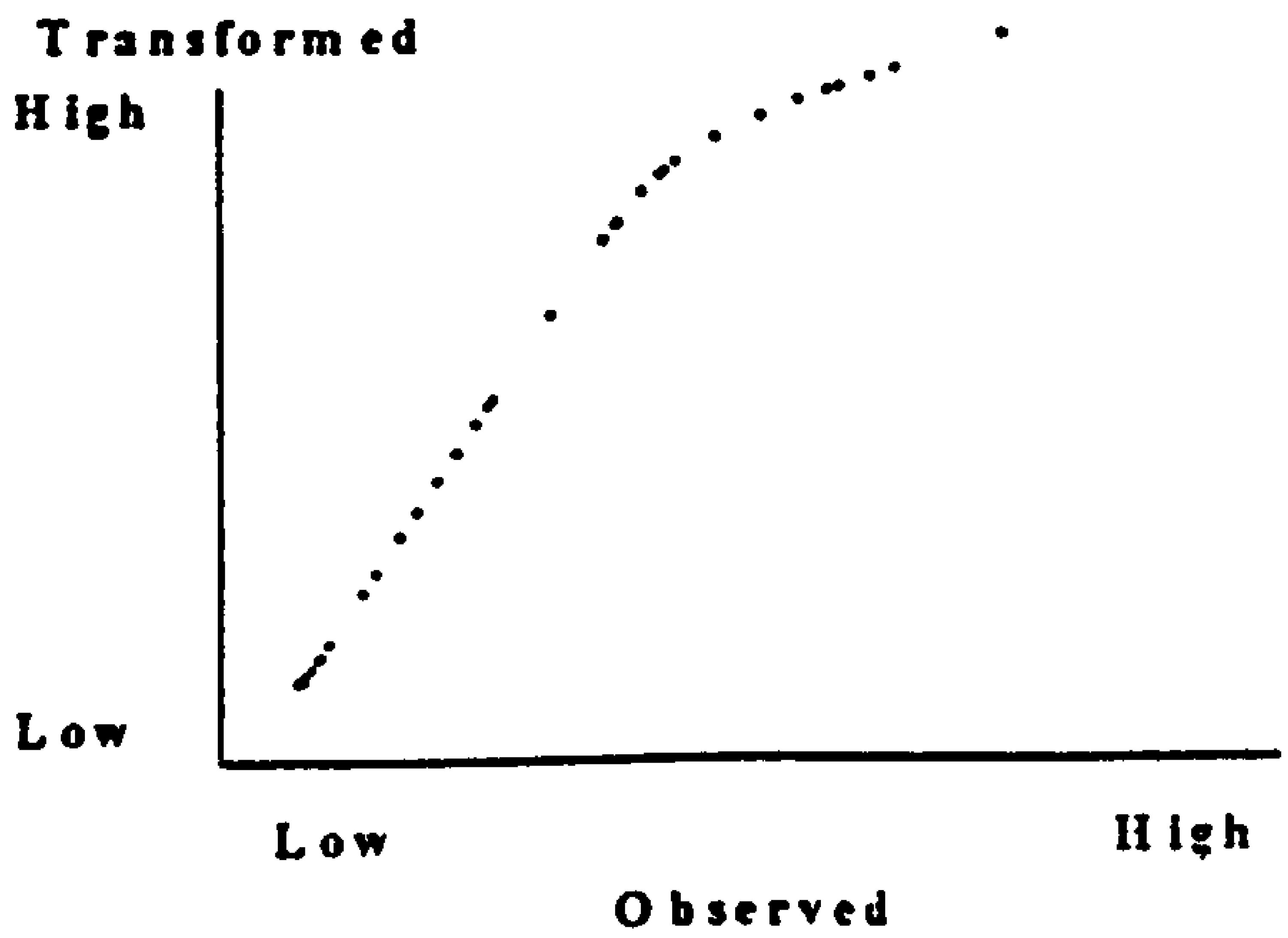
Figure 7.12 Transformations for Manufacturing Planning & Control



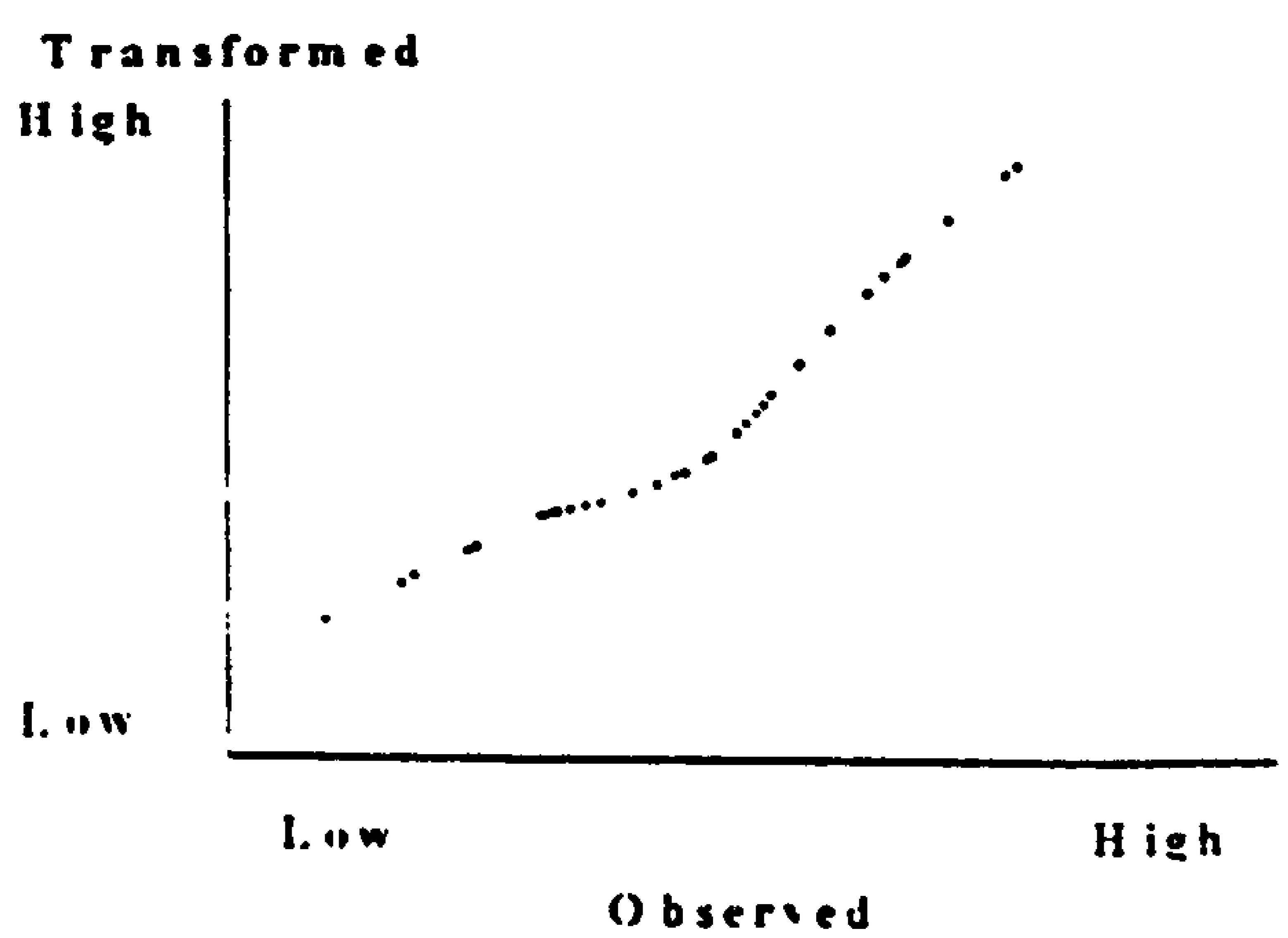
(a) Manufacturing P & C



(b) Yearin Implementation



(c) Supply Planning Data



(d) Demand Planning Data

7.4.4.8 Manufacturing Planning and Control

Table 7.8 shows that three independent variables are statistically significant and explained approximately 50.0% of the change in manufacturing planning and control among the Egyptian users. The variable transformations are displayed in Figure 7.12.

7.4.4.8.1 Year in implementation

Figure 7.12b suggests that increasing years in implementation has a positive, followed by a negative, then a positive impact on manufacturing planning and control. The positive impact of older system on manufacturing planning and control can be explained by user acceptance of the system as a result of prolonged usage (Sum et al., 1995). On the other hand, the negative impact may be as a result of the systems becoming conventional and the company needing to upgrade it to improve its business.

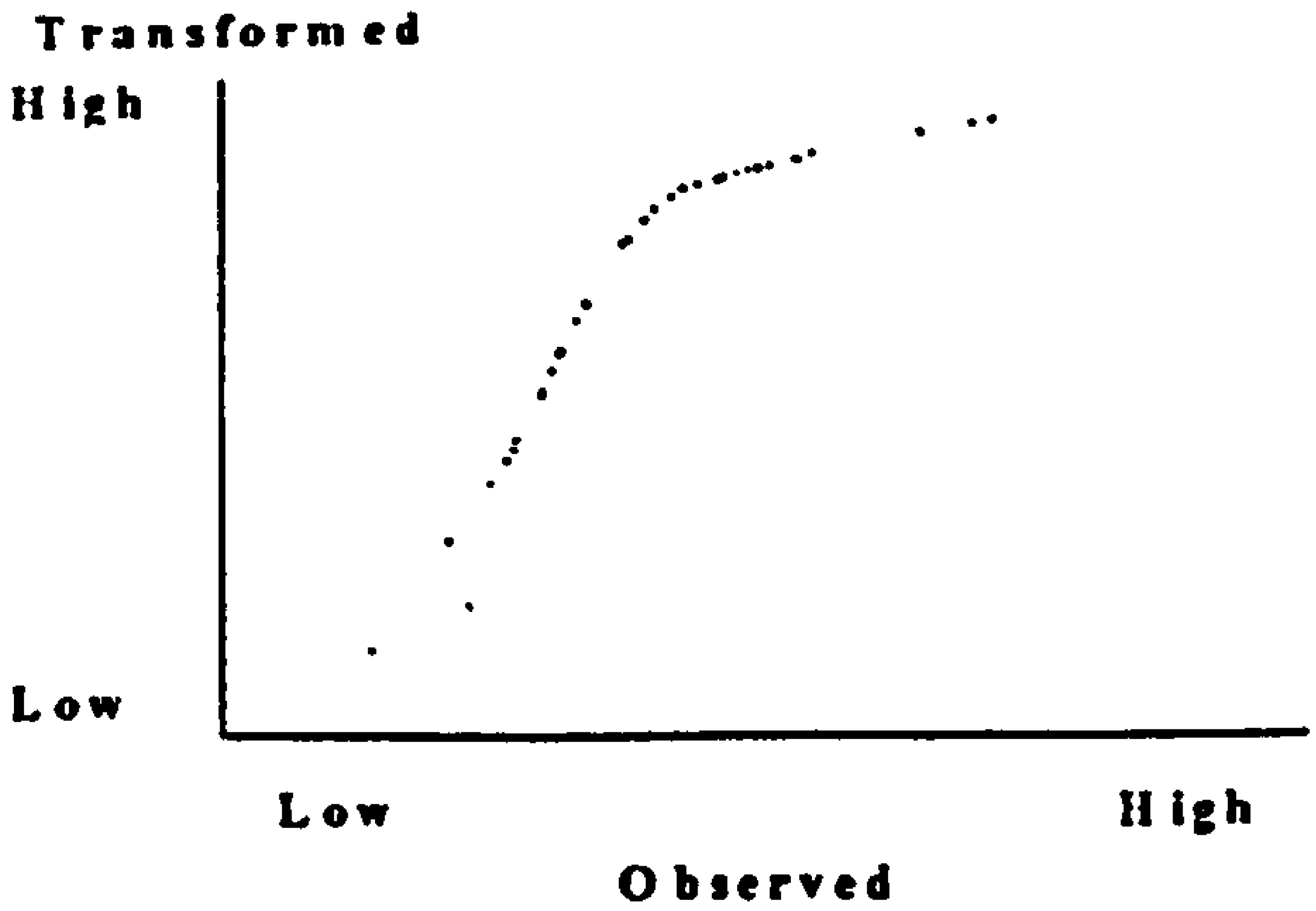
7.4.4.8.2 Supply planning data

The transformation for supply planning data in Figure 7.12c exhibits a positive impact on manufacturing planning and control. An explanation could be that supply planning data such as capacity data, vendor lead times and production lead times data may allow managers to obtain reports on the material flow, the right parts at the right place at the right time. This may be reflected in the efficiency of MPC system.

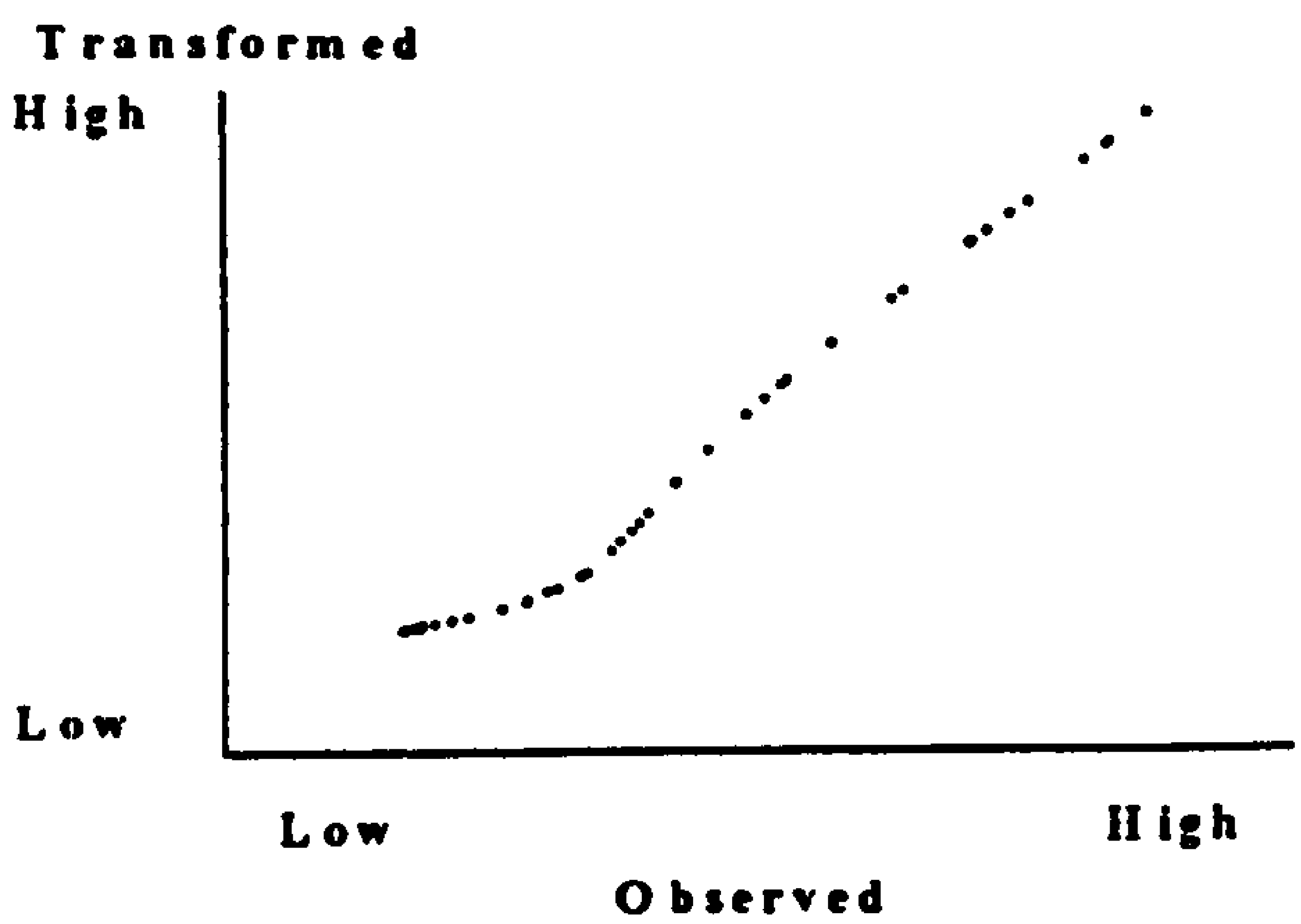
7.4.4.8.3 Demand planning data

The importance of demand planning data such as BOM, inventory and market forecasts data is reflected in Figure 7.12c which shows that as demand planning data increases, there is better manufacturing planning and control increases. This result supports the Schroeder et al. (1981); White et al. (1982) and Sum et al. (1995) findings concerning the importance of data accuracy for improving performance.

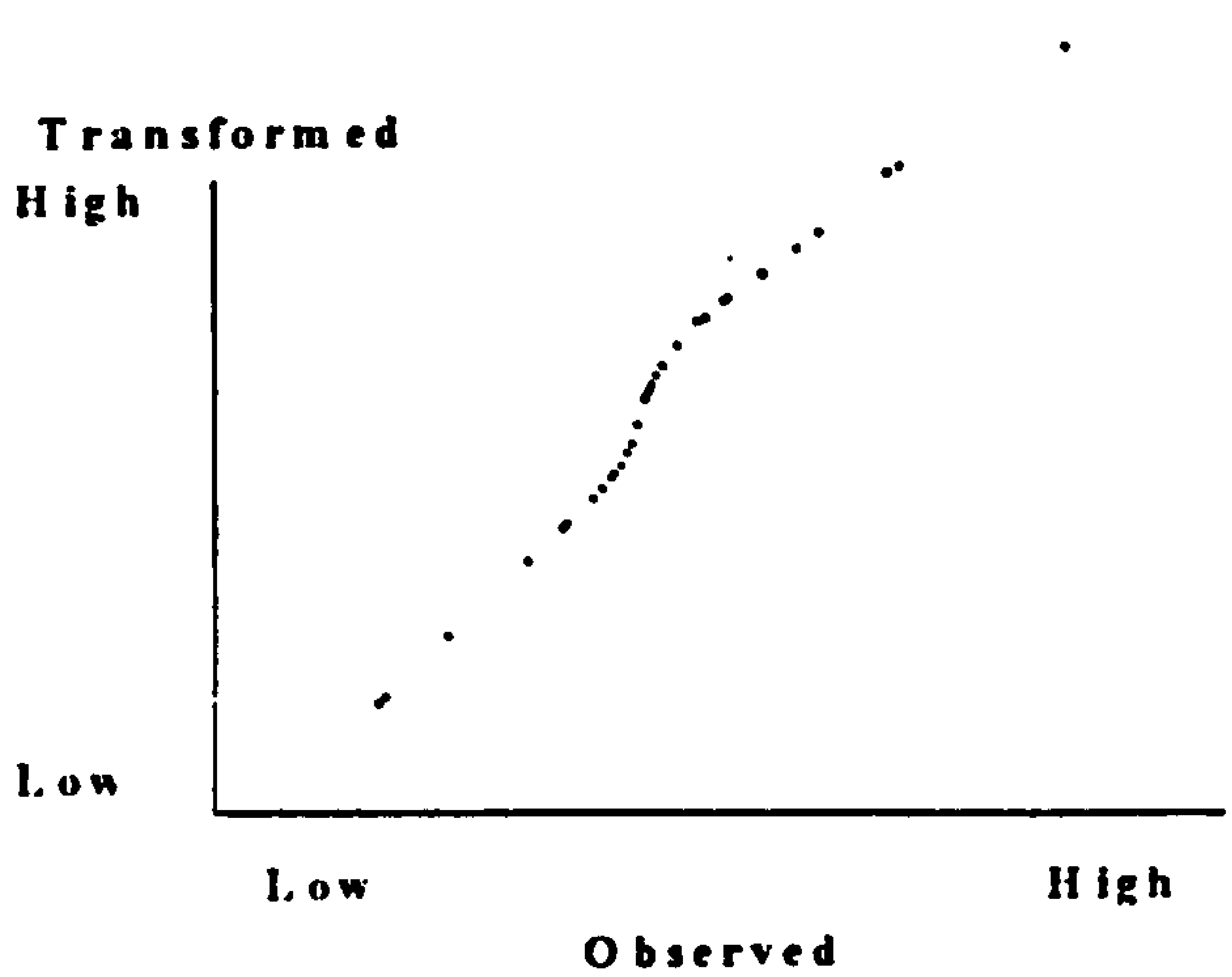
Figure 7.13 Transformations for Formal System



(a) Formal System



(b) Experience



(c) Technical Problem

7.4.4.9 Formal System

As shown in Table 7.8 the formal system benefit measure is affected by the degree of experience and technical problems. The results of the formal system model are statistically significant, with 47.0% of the variance in formal system accounted for. Figure 7.13 displays the variable transformations.

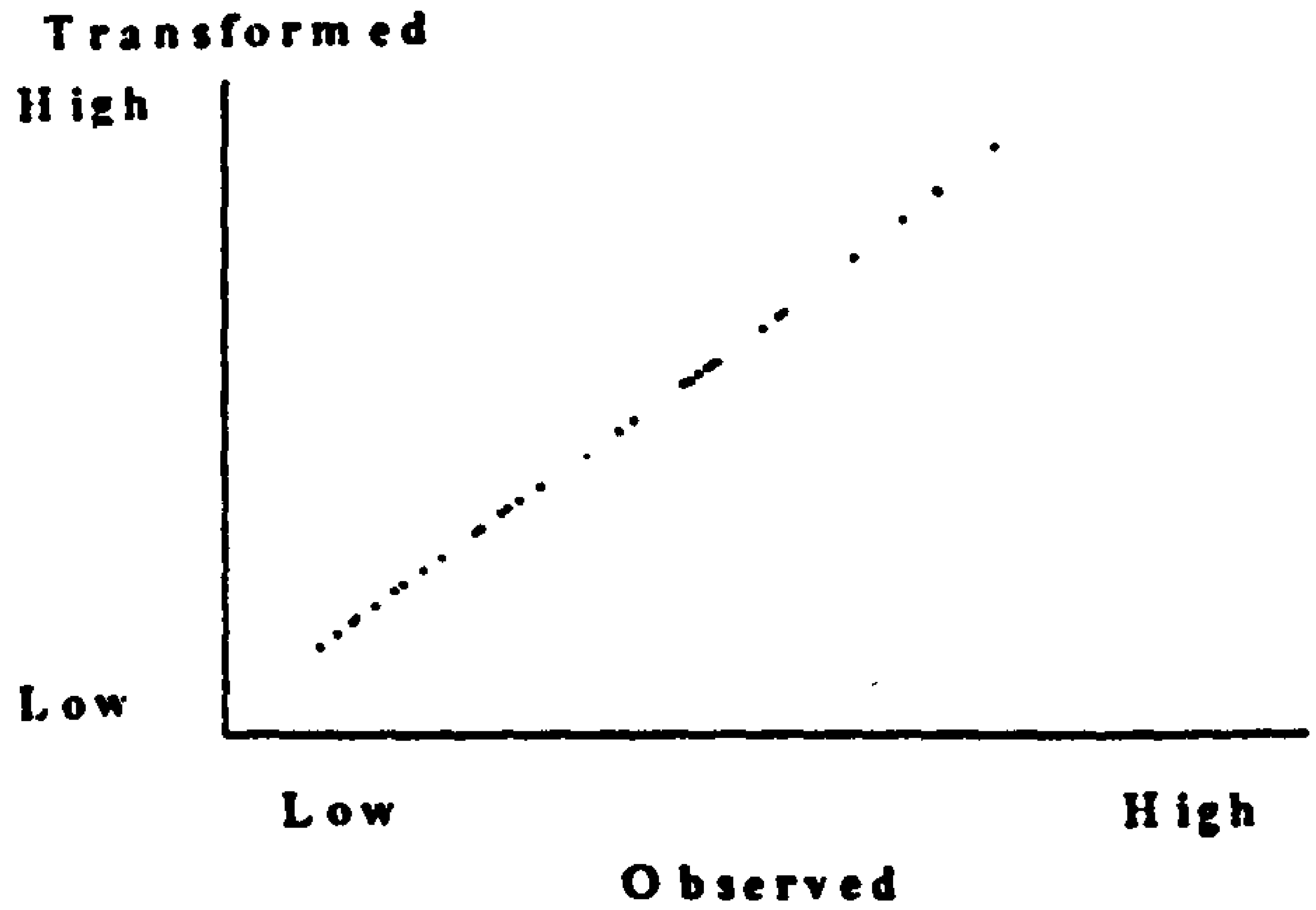
7.4.4.9.1 Experience with CAPM

Figure 7.13b suggests that increasing previous experience with CAPM systems has a positive impact on formal systems. This is expected, because increasing experience with automated information systems is likely to increase people's ability to understand and accept any prerequisites for a new formal systems such as the policies which describe how to perform business functions (e.g., forecasting, master production purchasing, cost accounting), procedures which describe how to enter and verify associated system transactions, and the distribution of responsibilities. The acceptance of these formal issues permit using the system, conducting business, and achieving data accuracy (Duchessi et al., 1989).

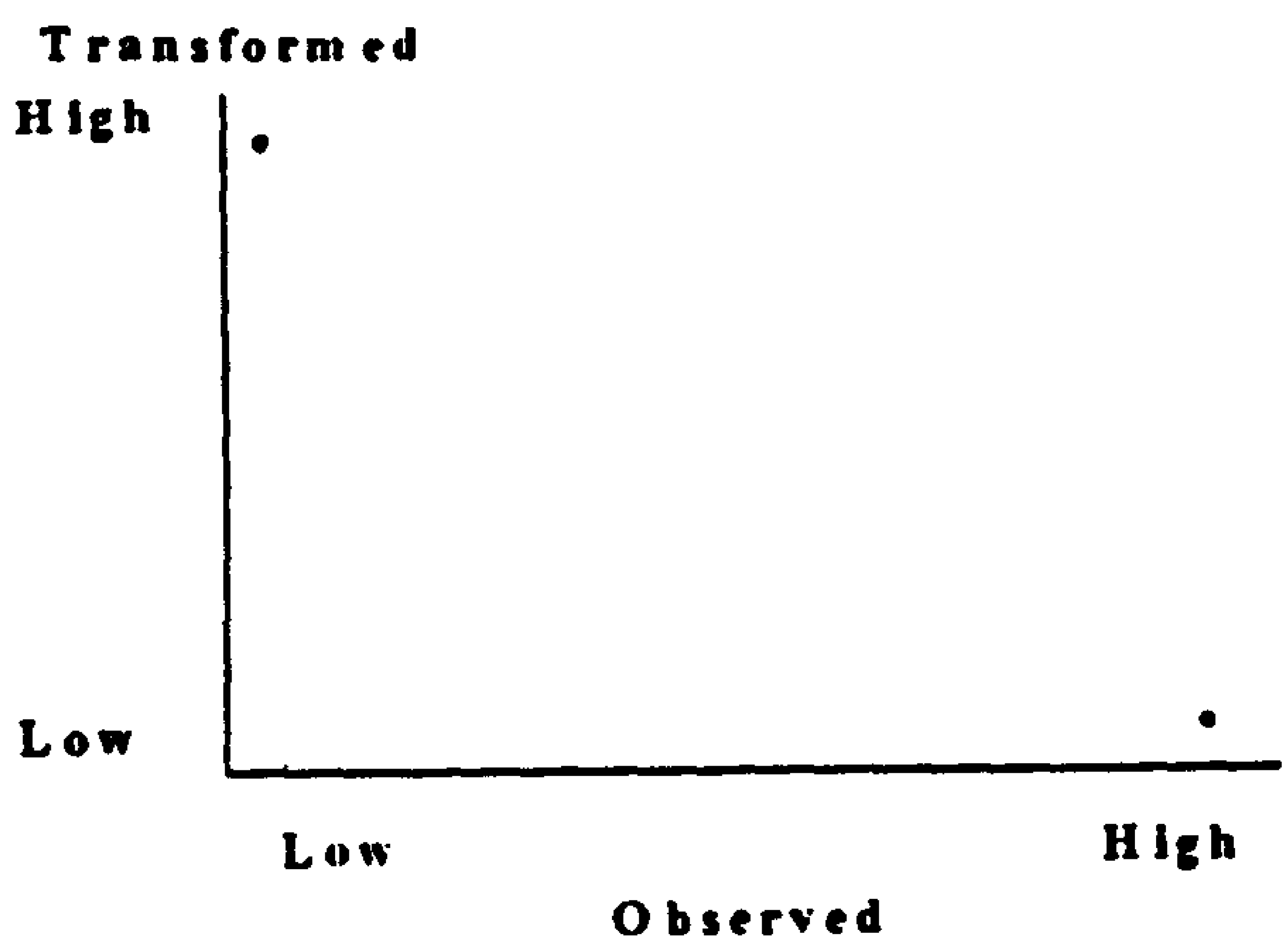
7.4.4.9.2 Technical problem

Figure 7.13c indicates that when few technical problems are encountered, low formal system benefits are reported. As the technical problems increase, the need for formal system increase in order to reduce informal systems for material management/inventory/production control and to increase BOM/inventory/MPS data accuracy. This result concurs with Sum et al.'s (Sum et al., 1995) finding that increasing technical problems have a positive followed by a negative impact on co-ordination among departments and sub-systems, and which may demonstrate the need for increasing formal systems to formalise policies, procedures and distribute responsibilities.

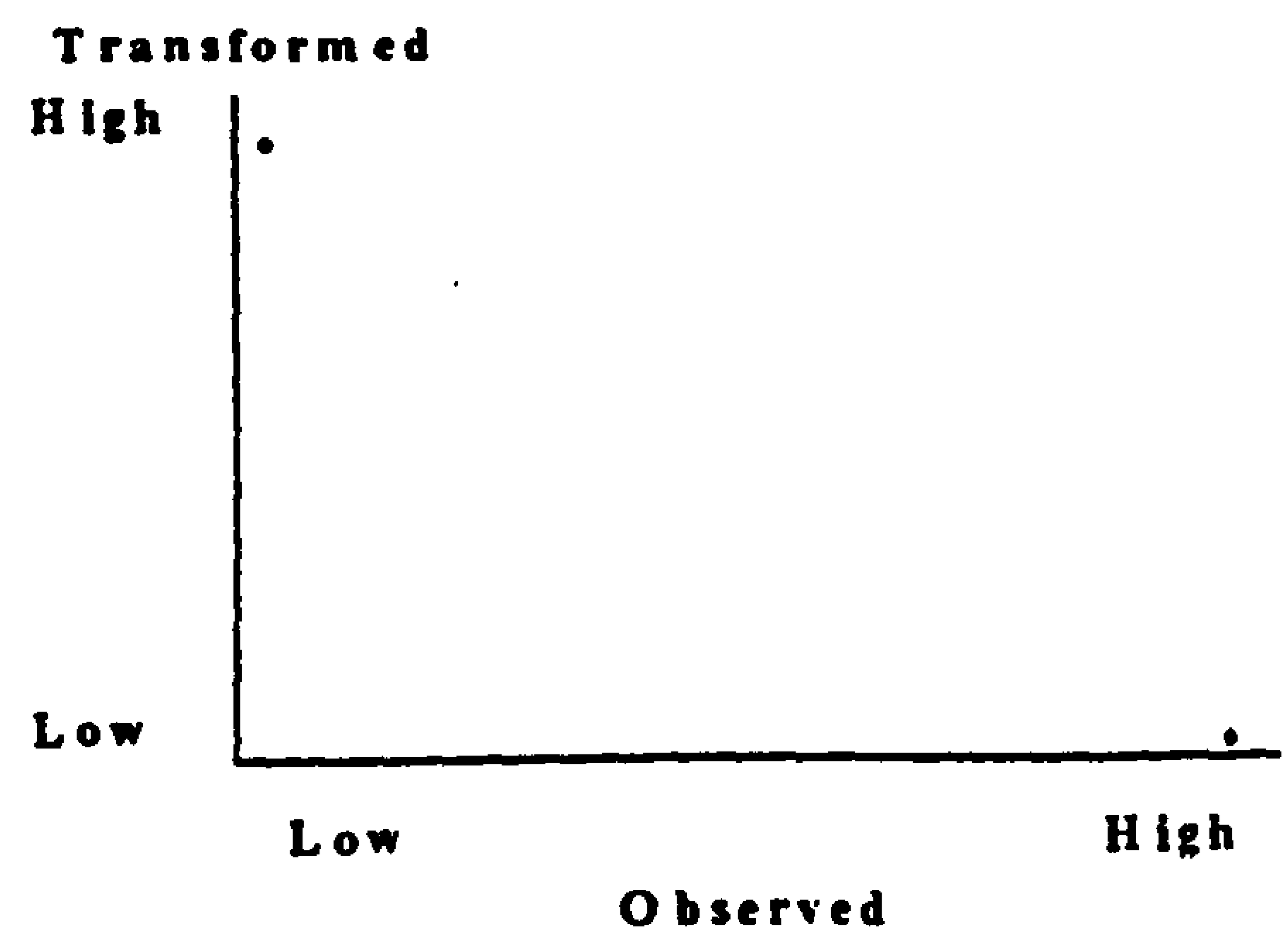
Figure 7.14 Transformations for Inventory Costs



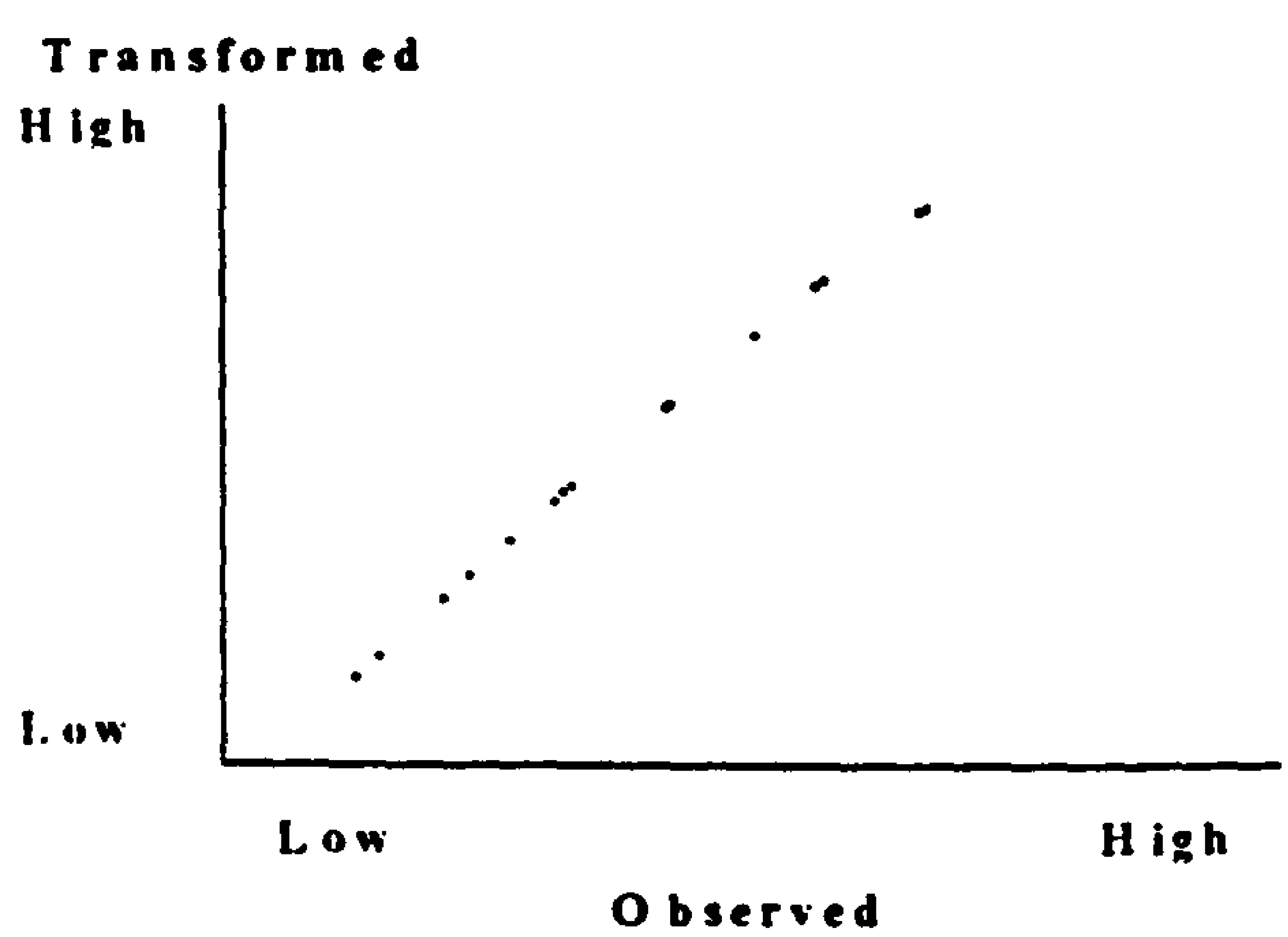
(a) Inventory Costs



(b) Manufacturing Strategy Dummy V.1



(c) Manufacturing Strategy Dummy V.2



(d) Levels in BOM

7.4.4.10 Inventory Costs

The ACE model of inventory cost benefit (Table 7.8) shows that inventory cost is affected by type of product and levels in bill of materials. Figure 7.14 displays the variable transformations.

7.4.4.10.1 Manufacturing strategy

The difference in the parameter estimates between make to order and make to stock variables concerning inventory costs benefit (Table 7.8) is .0650 (.0651 make to stock- .0001 make to order) in favour of make to order, namely make to order is highly statistically significant more than make to stock. This suggests that more reduction in inventory costs is obtained in make to order than make to stock where the last strategy has a higher inventory costs (Browne et al., 1996).

7.4.4.10.2 Levels in BOM

The upward trend in Figure 7.14c supports the notion that higher levels in BOM is accompanied by higher inventory costs. This result concurs with the fact that more levels in bill of materials means more inventory investment (ElKhouly, 1994; Plossl, 1995).

7.5 Summary and conclusions

The main purpose of the analysis in this chapter has been to test that uncertainty, organisational, implementational, technological, and human variables do not necessarily correlate with the benefits obtained from MRP implementation in a linear manner.

The hypothesis was tested using Alternating Conditional Expectation (ACE). It was partly supported. In so doing, Factor Analysis (*FA*) was employed to reduce the number of the subjective benefits measures to some smaller number by determining which relate each other and which appear to measure the same thing. Five out of fourteen subjective benefits measures were extracted. These are operational efficiency, co-ordination, manufacturing planning & control (predictability), formal system, and inventory costs. The subjective benefits measures within each factor were related to each other. In contrast, this technique was not for the tangible benefits measures because the data is numerical. In addition, 20 out of 40 uncertainty, organisational, implementational, technological and human determinant variables were extracted.

As the second MRP study to use the advanced ACE technique, our ACE models cover several interesting insights into the relationships between benefits obtained from MRP implementation and determinant variables beyond these from the first study conducted by Sum et al. (1995). This concerned an analysis of determinant variables of MRP benefits on 52 MRP companies in Singapore, such as uncertainty, vendor support and user profile factors in addition to measuring improvements in performance.

Having discussed the mathematical results of the relationships between uncertainty, organisational, implementational, technological and human determinant variables and the benefits obtained from MRP implementation, the following is a summary of findings:

1. In general terms, similar to the findings of the Sum et al. study there are surprising new insights regarding the relationship between determinant variables and the benefits obtained from MRP implementation as a result of using ACE transformations.

2. The level in bills of materials (BOM) appears to be a critical determinant variable in affecting inventory turnover, percent of split orders, number of expediters and inventory costs. This is expected because levels in BOM identifies the components parts of a final output product at each level and indicate the complexity of detailed material planning. Therefore, high levels in BOM increases the probability of increasing inventory. In turn inventory costs tends to increase and inventory turnover tends to decrease. Moreover, the percentage of split orders because of unavailable materials tends to increase as does the number of expediters.

3. Our results concerning the importance of data accuracy as an important factor for MRP implementation are consistent with past literature, which confirmed that degree of data accuracy, whether it was planning data such as inventory records data or execution data such as shop floor data, impacts on all benefits that can be obtained from MRP implementation. This study reveals that high data accuracy leads to shortened delivery lead time, increased percent of delivery promises achieved, increased operational efficiency, and increased coordination among departments within the company. This will be reflected in increasing the user's level of confidence in and acceptance of the system.

4. The literature review revealed that an adequate capacity enables a company to meet its customer needs. Our findings are consistent with past literature, where capacity uncertainty increases delivery lead time and the number of expediters increases in order to meet due dates.

5. Consistent with past literature, manufacturing companies implementing a make to order strategy attained increased inventory turnover and decreased inventory costs more than companies implementing a make to stock strategy.

6. Our findings show that management support and people support are critical to decreasing the percent of split orders, to increasing the percent of delivery promises, to improving coordination and to achieving operational efficiency. This suggests that management should understand the significance of informal systems alongside formal systems (MRP systems) in order to make users perform better.

7. Our findings indicate that stage of the MRP implementation can have a negative impact on both percent of split orders and number of expediters. This is consistent with past literature where a high stage of MRP implementation is associated with capability for both priority planning and capacity planning, and reductions in inventory and number of expediters needed.

8. Our findings indicate that company size can have a positive impact on operational efficiency. This may be because big companies may have the capability to successfully operate MRP systems in terms of having experts in automated information systems and increasing investment in advanced systems etc.

9. It is very interesting to note that there are no significant relationships between source of MRP system, MRP system features, company maturity, implementation strategy, user involvement, education and training, the required products, initiator of MRP effort, vendor involvement and vendor experience and the tangible and subjective benefits obtained from MRP implementation based on the points of view of the Egyptian users.

All in all, an analysis of the relationships between uncertainty, organisational, implementational, technological, and human determinant variables and the benefits obtained from MRP implementation using ACE technique created new insights into these relationships and which may help MRP users and managers to derive MRP practices which enhance its effectiveness.

CHAPTER EIGHT

Conclusion and Recommendations

8.1 Introduction

Having finished the presentation and analysis of the results of this study in the previous chapters, it is time now to present the concluding chapter which is composed of five main sections. The first section attempts to acquaint the reader the main conclusions based on a review of the literature and the survey undertaken by the researcher; the second section presents both theoretical and empirical implications of the study; the third section illustrates the main contribution of the study; the fourth section offers the limitations of the study and the final section provides suggested recommendations for further research.

While considerable efforts have been directed towards investigating the implementation of MRP systems based on case study analysis, only a handful of studies have been devoted to examine MRP practices based on empirical studies. Some of these studies were conducted in developed countries such as the US and others in newly industrialising countries such as Singapore, but none of them was conducted in less developed countries such as Egypt. Even though much is reported about the user's dissatisfaction concerning the benefits obtained from MRP practices, very little work has been done to assess the benefits obtained from MRP implementation. Besides, most of previous studies have attempted to establish the facts concerning the factors that influence MRP systems effectiveness without attempting to specify and measure all possible explanatory variables of such effectiveness.

Therefore, the main task of this study was to fill some of this gap, and three objectives represent the central concern of this study: a) to investigate the state of practice of MRP in Egyptian manufacturing companies, b) to assess the effectiveness of MRP practices measured by the real benefits obtained from MRP implementation in Egyptian manufacturing companies, and c) to explore and measure the MRP benefit-determinant relationships in Egyptian manufacturing companies.

The sample for the present study was 93 Egyptian manufacturing companies in the public industrial sector (population size = 200). It was broken down into MRP companies and Non-MRP companies (52:41). The data for this study were collected by a nine page questionnaire mail survey because the population of study is geographically dispersed.

The major findings of this research suggest that MRP implementation in Egypt is relatively similar to implementation in manufacturing companies in the newly industrialised countries and in the west. We conclude that the average company installing MRP has achieved significant benefits. The relationships between MRP benefits and determinant variables that influence them do not take a linear manner for several relationships and this may be advantageous for both MRP managers and users in managing these relationships effectively for achieving the effectiveness of MRP practices.

When we tested a suggested model framework of determinant variables of MRP implementation benefits in this study in the light of the basic data analysis, we found that the conclusions generally tended to support the model in some relations but not in others - see Figure 8.1 below:

Figure 8. 1 A suggested model framework of determinant variables of MRP implementation benefits.

Determinant Variables	**MRP Implementation Benefits**
Uncertainty Determinants	***Tangible Benefits***
Product characteristics diversity	Inventory turnover
Amount of aggregate product demand	Delivery lead time (days)
Machine downtime	Percent of time meeting delivery promises (%)
The standard of raw material	Percent of orders requiring "splits" because of unavailable material (%)
Behaviour of people within the factory	Number of expediters (number of people)
Reliability of plant within the factory walls	***Subjective Benefits***
Capacity constraints	Improved competitive position
Organisational Determinants	Reduced inventory costs
Company age	Increased throughput
Company size	Improved product quality
Type of products	Improved productivity
Type of Manufacturing	Better ability to meet volume/ product change
Layout	Better production scheduling
Company complexity	Reduced safety stocks
Organisational arrangements	Better cost estimation
Organisational willingness	Improved co-ordination with marketing and finance
Implementational Determinants	Improved your ability to perform in your job
Years in implementation	Reduced informal systems for materials management/ inventory/ production control
Implementation strategy	Increased BOM/inventory/MPS accuracy
Degree of data accuracy	Increased information on which to base decisions since MRP has been implemented
Initiator of MRP effort	
Software/hardware vendors support	
Implementation problems	
Technological Determinants	
Degree of integration among MRP modules	
Source of system	
System installation cost	
Additional investment over next 3 years	
User class (stage of MRP implementation)	
MRP system features	
Human Determinants	
The previous experience with CAPM Systems	
Education and formal training	
User involvement	
User support	
Degree of utilising the outputs of MRP	

Statistical analysis regarding reported benefits by the Egyptian users demonstrate that not all MRP users attain same MRP benefits because there are significant differences among MRP companies concerning one of the tangible benefits i.e. "a reduction in number of expediters" and three of the subjective benefits i.e. "improved product quality"; "better ability to meet volume/product change"; and "improved ability to perform a job" obtained from MRP implementation.

Non-linear relationships were discovered between certain determinant variables and MRP benefits (e.g., uncertain capacity and number of expediters; people support problems and co-ordination among internal departments). The next section summarises the main findings of the current study.

8.2 Main findings of the study

As a whole, the findings in the current study suggest that MRP practices in Egypt are relatively similar to those in Sum & Yang (1993) and Ang et al. (1995) in Singapore as a newly industrialising country; and Anderson et al. (1982) and Laforge & Sturr (1986) in the US as a developed country. Also, the study reveals that the implementation of MRP systems by Egyptian users is satisfactory because our survey indicates that MRP users believe that the expected benefits have been obtained. This is particularly striking because most of the companies who have installed MRP have done so only recently.

Furthermore, the findings in the current study show that there is a relationship between some uncertainty, organisational, implementational, technological and human determinant variables and the benefits obtained from MRP implementation. As a consequence, the empirical findings of the study can be summarised and concentrated in the following points which attempt to link them to the literature:

8.2.1 Findings regarding the state of practice of MRP systems in Egyptian manufacturing companies

The empirical findings indicate that the current usage of MRP system in Egypt is not very widespread, considering that out of the 123 respondents (usable and unusable), only 52 (42.3%) companies have implemented at least the basic modules of MRP system. However, this implies that the Egyptian companies are striving to improve their manufacturing efficiency and effectiveness with a better manufacturing planning and control system. On the other hand, a review of the literature indicates that the usage levels of MRP systems in other countries are approximately similar e.g., in Singapore 59 (46.1%) out of 128 companies surveyed by Sum and Yang (1993); Ang et al. (1995) and Sum et al. (1995), had implemented MRP systems, also in the US 433 (64%) out of 679 companies and 33 (31%) out of 107 companies surveyed by Anderson et al. (1982) and Laforge & Sturr (1986) respectively, had implemented MRP systems.

Consistent with past literature, the survey findings suggest that MRP implementation is more likely to be in engineering and electronic industries and less likely to be in other industries either in Egypt or Singapore or the US.

Companies are more likely to implement MRP systems when they are larger, older, complex, and their marketing strategy is a combination of make to order and make to stock products in the three countries. These findings also are consistent with past literature in related studies such as Anderson et al. (1982) in the US and Sum & Yang (1993) in Singapore.

The survey findings suggested that limited knowledge about MRP systems can be considered as the most important obstacle that impedes MRP implementation by the Egyptian and Singaporeian Non-users, while lack of MRP training, education and expertise were identified as critical problems encountered in the implementation process both in Egypt and in Singapore.

The current study reveals that most of MRP companies in Egypt are state owned; in contrast the majority of MRP companies in Singapore and the US are multi-national owned.

From the empirical evidence, the study indicates that the organisational arrangements for implementing MRP systems incline to be more formal by the US users (oldest users) than their peers in Egypt and Singapore.

Our study reveals that top management support in Egypt has a great impact on the extent and rate of the acceptance of MRP system more than their peers in Singapore and the US. The reason behind that may be because MRP companies in Egypt are still in an early phase of implementation (57.0% of companies under investigation had implemented MRP systems for 5 or less than 5 years) so top management are highly involved in MRP implementation or it may be a cultural difference.

The empirical findings indicated that there is a high reliance among Egyptian users on the vendors to provide the necessary assistance. The reason behind that may be that fact that local companies lack the necessary expertise in automated manufacturing systems in general and in MRP system in particular. In contrast, the vendor's role in the

US companies is less, perhaps the reason being that US users have had more expertise in the implementation of MRP systems than Egyptian users.

The empirical findings indicate that the Egyptian users are at the earlier stage of MRP implementation. Twenty five out of 52 MRP companies in Egypt claimed to be class C users which means that they use MRP system as an order launching system for managing inventory.

Consistent with past literature, the research findings revealed that the government is still a major player in the development of the manufacturing sector whether in Egypt or in Singapore. It promotes the implementation of MRP systems by manufacturing companies whether through providing support such as financial assistance, tax reliefs, and grants, or by providing education and training from the governmental institutions.

Our findings indicate that the majority of MRP systems run on mainframes and minicomputers rather than PCs in Egypt. Also, the majority of MRP companies in Egypt prefer to buy turn-key systems. This may stem from the Egyptian users seeking to take advantage of the services offered by vendors and to shorten the implementation time. This is consistent with the results of the Sum and Yang study (1995) concerning MRP practices in Singapore.

Consistent with past literature, the human aspects were found to be crucial in affecting the implementation of MRP systems in the local context. MRP users reported that they regarded education and training, top management commitment and users involvement as necessary requirements for implementing MRP systems.

8.2.2 Findings relating to the benefits obtained from MRP implementation by Egyptian manufacturing companies

The survey findings demonstrate the benefits from MRP already documented in developed countries such as the US and the newly industrialising countries such as Singapore, were also obtained by Egyptian users.

The research findings indicated that MRP users in Egypt, Singapore and USA are not only pleased with the improvements which were derived from MRP implementation, but also optimistic concerning further improvements when their MRP systems are fully installed.

The findings of the study indicate that the costs of MRP installation by the Egyptian users are less than their peers in the US. The reason seems to be that local companies are at earlier stage of MRP implementation i.e. the majority of MRP users are implementing MRP I, while the most of American users have implemented a complete Manufacturing Resources Planning (MRP II) system which is considered more sophisticated than MRP I and is more expensive and needs more training expenses.

In direct contrast to past literature, the findings found no relationship between the costs spent on MRP installation and company size suggesting that it is not only the large firms can implement in these expensive systems.

With the exception of a difference in the number of expediters among MRP companies, our findings provide strong evidence that there are no significant differences amongst the Egyptian users concerning the improvements and changes achieved and the expected progress from MRP implementation. This is partly inconsistent with past literature (Anderson and Schroeder, 1984; Duchessi et al., 1989) which suggests that not all MRP users attain the same benefits.

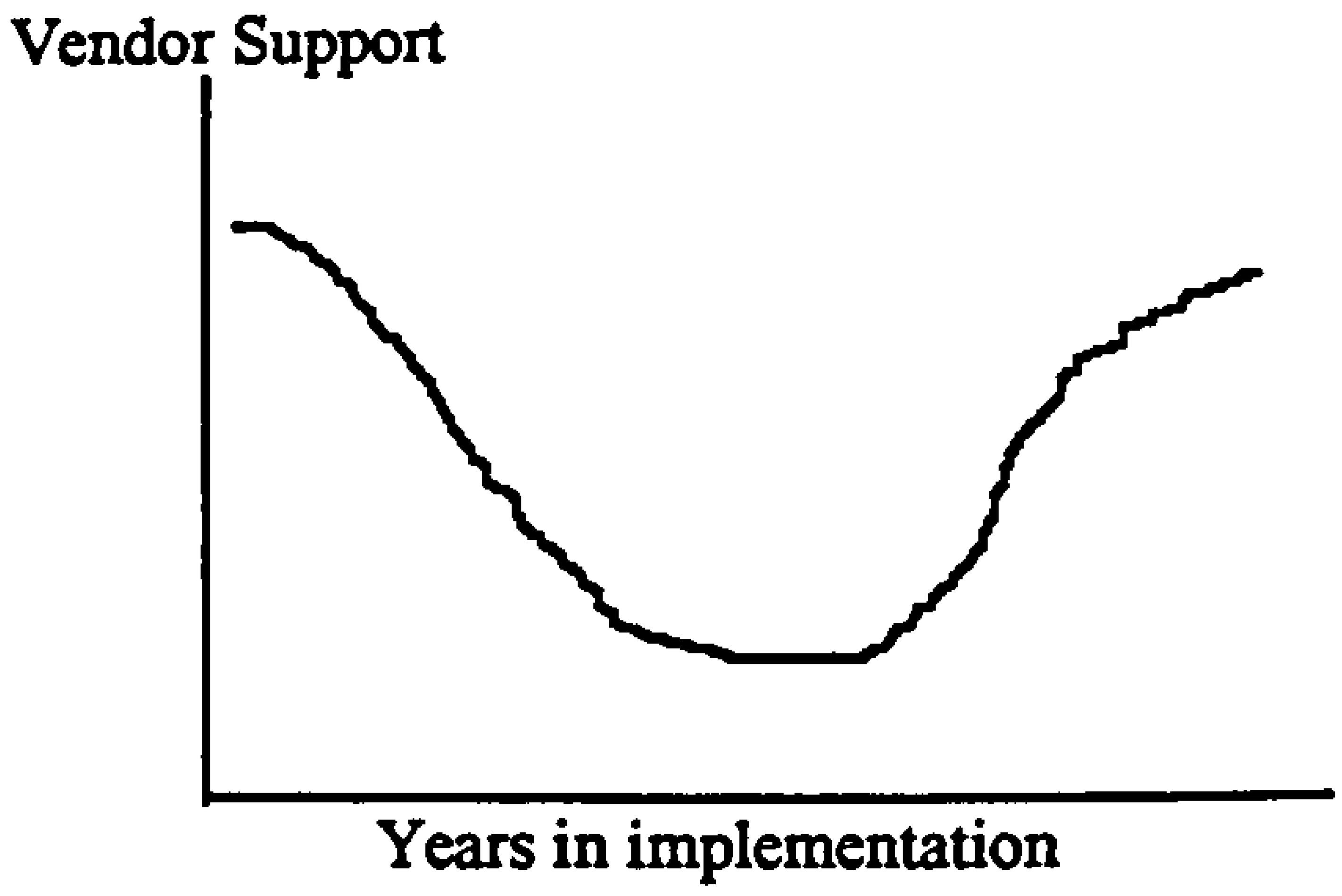
The study reveals that MRP benefits are not only restricted to the electronic and engineering industry as was generally believed in past studies but also those benefits can be obtained by the other manufacturing industry sectors such as: textile industry and food industry, though a smaller proportion of firms in these latter industries have adopted MRP.

8.2.3 Findings related to determinants of MRP benefits

Consistent with past literature, the benefits obtained from MRP implementation are significantly better in "make-to-order" than "make-to-stock" environments. Our findings suggest that MRP companies working in make to order environments obtained better inventory turnover and lower inventory costs than those companies working in make to stock environments.

In direct contrast to previous studies, our findings indicate that there is a non-linear relationship between vendor support and inventory turnover. This suggests that when a manufacturing company is a beginner in MRP implementation it has a lot of problems concerning the implementation of MRP system problems which may be reflected in reduced performance in areas such as inventory levels and inventory turnover. Therefore, it has a high reliance on the vendor to provide the necessary technical assistance. In process of time, MRP user becomes more familiar and more successful with MRP implementation, so, it expects less support from the vendor. But the company may decide to upgrade or develop its MRP system afterwards so its reliance on vendor support will increase again. This relationship can be depicted as shown in Figure 8.2 below:

Figure 8. 2 The relationship between vendor support and MRP user needs over time.



Levels in bills of materials (BOM) appear to be critical determinant variables in affecting several MRP benefits such as inventory turnover, percent of split orders, number of expediters and inventory costs. This is expected because high levels in BOM increases the probability of increasing inventory and in turn inventory costs tends to increase and inventory turnover tends to decrease. Moreover, the percentage of split orders because of unavailable materials and the number of expediters tend to increase.

Consistent with past literature, experience with CAPM systems was found to be crucial to increasing "formality" benefits such as developing new policies which describe how to perform business functions (e.g., forecasting, master production purchasing, cost accounting), new procedures which describe how to enter and verify associated system transactions, and the distribution of responsibilities.

Our findings indicate that as the technical problem increase, the need for formal system increase in order to reduce the use of informal systems for material management/inventory/production control and to increase BOM/inventory/MPS data accuracy. This result is consistent with previous studies concerning the impact of technical problem on the need for increasing formal systems to formalise policies, procedures and distribute responsibilities.

Consistent with past literature, data accuracy, whether planning data such as inventory records data or execution data such as shop floor data, was found to be crucial in affecting all the benefits that can be obtained from MRP implementation. This study reveals that high data accuracy leads to shortened delivery lead time, increased percent of achieved delivery promises, increased operational efficiency, and increased co-ordination among departments within the company. This should be reflected in increasing the user's level of confidence in and acceptance of the system.

Our findings indicate that adequate capacity enables a company to meet its customer needs. Where capacity uncertainty increases, delivery lead time and number of expediters increase in order to meet due dates.

Consistent with past literature, manufacturing companies have implemented make-to-order strategies attained increased inventory turnover, and decreased inventory costs more than those who have implemented make to stock strategies.

Our findings show that management support and people support are critical in decreasing the percent of split orders, increasing the percent of delivery promises, improving co-ordination and achieving operational efficiency. This suggests that management should understand the significance of the informal system alongside the formal system (MRP system) in order to make users perform better.

Our findings indicate that the stage of MRP implementation can have a negative impact on both percent of split orders and number of expediters. This is consistent with past literature where it is in later stages of MRP implementation that there is capability for both priority planning and capacity planning, reductions in inventory take place and more expediters are needed.

Our findings indicate that company size can have a positive impact on operational efficiency. This may be because big companies may have greater capability to successfully operate MRP systems in terms of having experts in automated information system and bigger investment in advanced systems etc.

Inconsistent with past literature, our findings indicate that there is no significant impact of several determinant variables, such as source of MRP system, MRP system features, company maturity, implementation strategy, user involvement, education and training, the required products, initiator of MRP effort, vendor involvement and vendor experience on the benefits obtained from MRP implementation by the Egyptian users.

8.3 Implications of the study

The study findings appear to have theoretical and practical implications for both MRP managers and users in Egyptian manufacturing companies and for researchers. Therefore, the following theoretical and practical implications can be drawn:

(1) One of the main implications of the current study is that it has shown that competitive position was not one of the major reasons for MRP implementation by the Egyptian manufacturing companies. A majority of MRP companies in Egypt indicated that the most important reasons for implementing MRP systems were operational and not

strategic reasons. Lowering inventory cost and meeting delivery dates better were the kinds of reasons given, suggesting that MRP systems were not viewed as a competitive strategy weapon.

(2) Another implication of this empirical study is that the governmental role represents a highly salient factor for developing the industrial sector in Egypt. Manufacturing companies indicated that they rely on the government not only to promote MRP systems but also to provide support (e.g., grants, incentives), and to run the relevant education/training programmes for achieving successful implementation. This reflects the extent to which the public sector still dominates control structures over industry in Egypt.

(3) A very significant implication is that user's involvement was found to be crucial to implementing MRP systems. In this regard, manufacturing companies can encourage MRP users to be more involved in the implementation process whether by taking account of their comments and recommendations or by increasing incentives such as rewards. Also, they can run the appropriate training courses whether on site, at the educational institutions or at private and government training agencies.

(4) Managers in manufacturing companies within Egyptian industrial sector can use the instrument used in this study to evaluate the expectations and perceptions of MRP users concerning the tangible and intangible benefits obtained from MRP implementation in their organisations. These measures can help top management to know how MRP is being used, to concentrate on key areas to maximise MRP benefits that match their company goals and to identify those areas of MRP practices where improvements should be made.

(5) Western managers can get a better understanding of the MRP practices in Egypt based on the empirical findings provided. In today's global economic environment, companies are often looking for business partners all over the world. Understanding of how manufacturing companies in other countries such as Egypt are exploiting a powerful technology such as MRP systems for gaining competitive advantage is very important for decision makers in Western corporations.

(6) Another implication for software and hardware MRP vendors (e.g., ICL company which is seeking nowadays to distribute its product of Manufacturing Control System - MAX in Egypt) is that they can get a better understanding of the state of practice of MRP systems in Egypt. In turn they can formulate the relevant strategies which enable them to meet the current and expected user needs.

(7) The empirical findings of this research are educational and informative for non-users and potential users of MRP. They can take advantage of the experiences of the current users which provide a preview of what they can expect to face and the traps that they can avoid when they acquire MRP.

(8) Poor training/education on MRP and lack of company expertise in MRP were viewed as the major implementation problems. Therefore, the need for MRP education and training is highly stressed. In turn, MRP vendors, educational institutions and government training agencies can meet this need through preparing appropriate programmes and courses for MRP users.

(9) As the cost of MRP installation by the Egyptian users has not been considered as a major barrier to adopt MRP systems and also is less than their peers in the US, this can

be considered as a good incentive for the decision makers in non-MRP companies to plan and promote MRP implementation in their organisations.

(10) With the empirical findings of the effectiveness of MRP systems measured by the benefits obtained from MRP implementation, greater attention should be paid by current and potential MRP users to MRP practices. Greater MRP systems effectiveness will place the Egyptian manufacturing sector in a competitive position in the international arena.

(11) As the empirical results indicate that data accuracy appears to be critical in affecting the benefits obtained from MRP implementation, managers and users must devote more effort to maintain data accuracy at a high level if they want to obtain significant benefits from their MRP systems.

(12) The linear and non-linear relationships between uncertain capacity and the benefits obtained from MRP implementation suggest that MRP managers must expend extra effort to estimate the right capacity (usually in hours) of each machine or work centre in order to maintain the efficiency of their production planning and control system.

(13) The negative impact of increased levels in bill of materials (BOM) on the benefits obtained from MRP implementation addressed by the current study suggests that managers in the production departments in non-MRP companies with low levels in BOM such as food and textile industries can be shown that the implementation of MRP systems is not restricted to complex companies (i.e. companies with high levels in BOM), but could be applicable in their companies.

(14) Our empirical results indicate that as company size increases the need for more expediters increases, also as size gets too big the operational efficiency increases. This provides a new insight into management which means that an extended size is not necessary to achieving the full effectiveness of MRP systems. On the other hand, this is a good sign for decision makers in small size companies who are hesitating to adopt MRP system due to size considerations indicating that they might be able to implement and operate an MRP systems effectively.

(15) A very significant implication is that the stage of MRP implementation was found to be crucial to the benefits obtained from MRP implementation. This suggests that management commitment must be extended for implementing an advanced stage of MRP system if they want to realise more benefits from their MRP system.

(16) Our findings suggest that there is a positive impact of "people support" on the benefits obtained from MRP implementation. The main implication is that people problems should be monitored very closely by managers and also they have to understand that informal systems should exist and be sustained alongside the formal system if they want to attain significant benefits from their MRP system.

(17) The non-linear relationship between people support problems and co-ordination among departments may suggest that top management should monitor MRP usage among different departments such as production, finance, and marketing departments, if they want to achieve the effectiveness of MRP implementation.

(18) Our findings indicate that MRP companies set up formal steering committees to oversee the implementation of MRP systems, have these committees meet regularly, and

have someone with full responsibility for the MRP project. This suggests that top management support should be provided and also organisational support across functions and levels in the company should be generated, if MRP users want to achieve successful implementation of their MRP system.

8.4 Contributions of the study

It is hoped that this study will make several contributions, mainly in the following areas:

8.4.1 Theoretical contributions

(1) This study contributes to the development of the body of the literature showing the role of developments in manufacturing planning and control systems such as MRP, JIT and OPT systems in increasing the ability of a company to face dramatic changes in the business environment.

(2) A very significant contribution of this study is its extensive comparison with results obtained by previous studies elsewhere. Comparison is made between preceding studies of MRP implementation in developed countries and in the newly industrialising countries, and MRP implementation in a less developed country, namely Egypt.

(3) There is a large body of earlier work on MRP practices to which this study relates but most are exploratory, and have been conducted based upon case studies. This study is not only exploratory, it is empirical, descriptive and quantitative.

(4) This study has also a wider coverage in terms of the scope of the key issues about MRP practices. It investigated MRP company profile (i.e. size, age, type of manufacturing systems, type of manufacturing processes), MRP system characteristics

(i.e. hardware and software, degree of computerisation, degree of integration, system features, MRP definitions), the stage of MRP implementation (i.e. user class), MRP implementation (i.e. initiator of MRP, implementation problems), MRP systems growth, factors that may impede non-users to implement MRP systems and finally the main areas for promoting MRP systems based on the point of view of MRP users within Egyptian manufacturing companies.

(5) Compared with the previous studies our study is the first large-scale study concentrating on specific MRP benefits, namely nineteen measures of the benefits of MRP implementation which are broken down into two groups a) the tangible benefits which comprise five performance measures, and b) the subjective benefits which consist of fourteen intangible benefit measures. On the other hand, Sum and Yang (1993) investigated ten subjective benefit measures in order to assess the benefits obtained from MRP implementation in Singapore, Anderson and Schroeder (1984) investigated five tangible benefits in their study regarding the results obtained from MRP implementation by the American companies, while Sum et al. (1995) investigated thirteen subjective benefits in their study concerning the MRP benefit-determinant relationships in the Singaporean context.

(6) Regarding the MRP benefit-determinant relationships, the current study has a wider coverage in scope of the explanatory variables of MRP systems effectiveness measured by both tangible and subjective benefits obtained from MRP implementation, more than Sum et al. (1995), who found that there are linear and non-linear relationships between a set of organisational, implementational, and technological determinant variables and the

subjective benefits obtained from MRP implementation by the Singaporean users. This study investigated the relationships between a set of uncertainty, organisational, implementational, technological, and human determinant variables and the tangible and subjective benefits obtained from MRP implementation by the Egyptian users. In the same direction the results show that there are linear and non-linear relationships between MRP benefits and their determinant variables.

8.4.2 Practical contributions

(1) This study contributes to what is currently a very limited amount of empirical research on MRP practices. Therefore, its conclusions are less biased by limitations of personal experience than most of the previous studies.

(2) No study has been done concerning MRP practices whether in developed countries or in the newly industrialising countries providing the large number of empirical implications for both MRP managers and users like the current study.

(3) Since only one previous study examined the MRP benefit-determinant relationships using Alternating Conditional Expectations (ACE transformation) technique, the current study is only the second study to explore and examine the MRP benefit-determinant relationships using the ACE transformation. This novel technique gives surprising new insights regarding the relationship between dependent and independent variables. For instance the relationship between people support problems and co-ordination among departments does not take a linear form - the ACE transformation shows that people support problems decrease then increase along with co-ordination among departments.

(4) This study contributes in blending the literature from various disciplines, especially production management, organisation behaviour, and information systems, to explain the findings from the data analysis.

(5) Another contribution achieved by undertaking the current study is to provide useful comparative data for academics as it is the first attempt to investigate the state of MRP practices in a less developed country, namely Egypt.

(6) This study contributes to what is currently a very limited amount of empirical research on the costs of MRP installation and the benefits obtained from MRP implementation in one study.

(7) This study contributes to what is currently a very limited amount of empirical research on measuring the level of for each of the five performance measures by taking account of the future-MRP benefit estimate based upon the expectations of MRP users.

(8) This study invites the researchers in less developed countries in general and in Egypt in particular to give more attention to MRP implementation studies on the basis that this study is the first concerning the state of practice of MRP systems in developing countries as far as the researcher is aware.

8.5 Limitations of the study

During the carrying out of this study and also in interpreting the results several limitations were encountered.

(1) The scarcity of literature in respect of MRP practices within manufacturing companies in developing countries in general and in Egypt in particular. Therefore, comparison was made with the most notable studies on MRP practices whether in

developed countries or in the newly industrialised countries such as Anderson et al. (1982) in the US; Sum and Yang (1993) and Sum et al. (1995) in Singapore.

(2) The generalisation of the findings of this study are limited to the Egyptian industrial public sector, not including the Egyptian industrial private sector.

(3) The decision was made to ask respondents to state their expectations based on their experience and not to provide the raw data regarding performance measures in three cases a) the pre-MRP estimate, b) current estimate, and c) future estimate for three main reasons: a) as part of this study involves comparing the Egyptian survey with the previous surveys i.e. Schroeder et al. (1981); Anderson et al. (1984); Anderson and Schroeder (1984) and Laforge & Sturr (1986), we have chosen to adopt the same strategy as used by them i.e. asking respondents to state their expectations based on their experience, b) it was felt that the responding companies were unlikely to be able to keep track of performance measures such as inventory turnover, number of expediters etc. over time, because of the lack of records in the companies or the confidentiality of the data, and also c) the fact that the companies are at an early stage of MRP implementation (57% of the companies having implemented the system for 5 or less than 5 years), and limited formed assessment of effectiveness based on performance measures would have been made.

(4) The *ABCD* checklist suggested by Wight (1981) to measure MRP systems effectiveness in the US, is not adopted by the current study because a different situation existed in the US and Egypt concerning the stage of MRP implementation. Furthermore, because the *ABCD* checklist is intended to measure companies that have implemented a

complete Manufacturing Resources Planning (MRP II) system, it is not applicable in the local context because the Egyptian users were still relatively beginners, namely they have implemented MRP I and have not achieved the status of MRP II users. Therefore, the tangible and intangible benefits obtained from MRP implementation were claimed to measure MRP system effectiveness, on the basis that a system is effective if it achieves its objectives.

(5) The term "implementation" is used as a broad term to include pre-implementation, implementation, and post- implementation stages as in Duchessi et al. (1988); Sum and Yang (1993) and Sum et al. (1995).

Despite these inherent limitations, the findings of this research should be useful in contributing to the local pool of knowledge to explore the state of practice of MRP system in Egyptian manufacturing companies as well as providing groundwork for further research.

8.6 Recommendations for further research

Since this study is considered as the first attempt to investigate the state of practice of MRP implementation in less developed countries in general, and in Egypt in particular, directions for further research are suggested:

(1) Further research should be undertaken to monitor the progress and status of MRP usage in Egypt over time. This may provide useful insights into the current trend and development in the implementation of MRP systems by the Egyptian users.

(2) The recommendation is made for further comparative studies with other less developed countries which could find out the similarities and dissimilarities concerning MRP implementation.

(3) Case studies need to be conducted to present more details concerning MRP implementation processes.

(4) Investigation is needed about MRP implementation in the private sector in comparison with the public sector.

(5) The major findings of this research indicate that the critical factors affecting the successful implementation of (MRP) systems within manufacturing companies are varied and interrelated together. This implies that an in-depth analysis of each factor or each group of factors at the most is required.

(6) Empirical research should be conducted to explore and examine the critical factors influencing the stage of MRP implementation in Egypt which may help to determine the progress of MRP usage.

(7) As noted, there is a trend towards a hybrid MRP with the other new production management systems such as JIT and OPT systems within the CIM context. Future studies can be based on the evaluation of such a hybrid system and identifying the unique set of critical success factors.

(8) As the current study has been considered the second attempt to explore and examine the MRP benefit-determinant relationships using the Alternating Conditional Expectations (ACE), future studies could be conducted to validate the findings presented in this study.

(9) The model of determinant variables of MRP benefits in this study adds new groups of determinant variables i.e. uncertainty and human variables in addition to new variables, e.g., vendor support. Therefore, it will be very useful to assess the relevance of this model in other contexts.

8.7 Summary

As presented, the research has been based on a comprehensive review of related literature and a thorough examination of the state of practice of MRP systems. As observed, investigating the MRP benefit-determinant relationships was offered as one of the solutions for achieving the effectiveness of MRP implementation. Effectiveness is the main indicator which can help to present the state of practice of MRP systems.

In contributing to this debate this thesis represents the largest survey on MRP practices in terms of coverage in scope, and offers added factors to be taken into consideration, particularly examining the effects, and relationship of, uncertainty factors on the benefits obtained from MRP implementation.

It is hoped that Egyptian manufacturing companies will pay attention to the results and note its proposals. It is hoped, too, that the study will open new dimensions for other researchers to execute more research in the field of the state of practice of MRP systems and to merge with other related disciplines such as information systems, finance and marketing, which can contribute to a better understanding, and to the enhancement, of MRP practices whether in developed countries or in less developed countries.

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APPENDICES

Appendix A
Questionnaire

QUESTIONNAIRE ON MRP
SYSTEMS IMPLEMENTATION

To be completed by the production managers or materials managers or inventory control managers or master schedulers or management information system managers in the Egyptian public manufacturing companies.

PURPOSE OF THE STUDY

The main task of this study is to explore and examine the MRP benefit-determinant relationships to permit MRP managers and users to obtain a better understanding of MRP systems practices and which enable them to concentrate on key areas to achieve benefits that match their company goals in the Egyptian public manufacturing companies.

GENERAL INFORMATION FOR COMPLETION

When answering the questions please keep the following in mind:

(1) This study is addressed to the Egyptian public manufacturing companies.

(2) The questionnaire should be answered by the production managers or materials managers or inventory control managers or master schedulers or management information system managers within a factory.

(3) The questionnaire has been designed with the aim of minimising the time required for completion. consequently, alternative answers are provided for most questions so you simply has to tick the response (s) which most accurately describe your opinion or the company's practice.

(4) The survey applies to **MRP** companies and **Non-MRP** companies in the sectors under investigation.

(5) The term **(MRP)** systems is used as a general term to include all versions of **MRP** systems, namely, **MRPI** (i.e. materials planning for order launching), **Closed-Loop MRP** (i.e. MRP1 with capacity planning and shop floor control), **MRPII** (i.e. Closed-Loop MRP integrated with finance, marketing, accounting, etc., and with simulation capabilities).

(6) The term of others is provided at the end of most of responses for any response (s) you have opined that it or them should be considered but the questionnaire ignore it or them.

(7) If any information is requested which is not routinely available, reasonable estimates will suffice. Please be assured that response based on informed judgement is infinitely more valuable than no response at all.

(8) All the information collected will be treated confidentially. Only the researcher will have access to your responses.

(9) Space is provided at the end of questionnaire for any comments you may wish to make about it. You are also asked to provide your name, your job title and the company's name so that a report summarising the results of this study will be made available to you later. Thank you for your support, and if you have any problems in completing the questionnaire, do not hesitate to contact me:

Mr. Salah Eldin Ismail **Tel. (047) 801 043 & (047) 801162**

SECTION I - Preliminary information

The aim of this section is to obtain background information relating to the companies under the investigation.

Q.1 Your title is (Please tick (/) where appropriate)

.... Production manager
.... Materials manager
.... Inventory control manager
.... Master scheduler
.... Management information system manager
.... Others..

Q.2 Your industry is (Please tick (/) where appropriate)

.... Electronic and engineering industry
.... Chemicals industry
.... Food industry
.... Textile industry
.... others...

Q.3 The ownership of your company. Please tick (/) where appropriate

.... Government
.... Private
.... Multi-national corporation

Q.4 If you was asked to describe your company characteristics? Please tick (/) where appropriate

a) Type of your products.
a) Make to order only ( )
b) Make to stock only ( )
c) Make to stock and make to order ( )

b)Type of manufacturing
a) Assembly only ( )
b) Fabrication only ( )
c) Assembly and fabrication ( )
d) Continuous/process flow ( )
e) Others .... ( )

c) Type of processes (layout)
a) Job shop ( )
b) Continuous process ( )
c) Assembly line ( )
d) Combination ( )

d) How many years has your company been in operation?
a) Less than 3 years ( )
b) 4-5 years ( )
c) 6-10 years ( )
d) 11-15 years ( )
e) More than 15 years ( )

Q.5 Your company size

a) Gross sales (millions)
.... Less than L.E10 millions .... L.E 10-20 millions
.... L.E 21-30 millions .... L.E 31-40 millions
.... L.E 41-50 millions .... More than L. E50 millions

b) Number of employees
.... 25-99 .... 100-499 .... 500 or more than 500

c) Number of production & inventory control employees
.... Less than 10 .... 10-20 21-30
.... 31-40 .... 41-50 .... More than 50

Q.6 Listed below the parameters for characterising product structure complexity.
Please tick (/) one box for each parameter listed.

a) Number of items per product **up to 32** [ ] **32-64** [ ] **64-100** [ ] **Over 100** [ ]

b) Number of levels in the bill of materials **up to 3** [ ] **3-5** [ ] **5** [ ] **5-7** [ ] **over 7** [ ]

Q.7 Listed below are several areas that could be used for promoting MRP systems in an industry.
Please indicate the level of importance for each area of them currently.
Please tick (/) one score for each area listed. **1=Not important at all 5=Extremely important**

a) Government support (e.g. grants, incentives)	1	2	3	4	5
b) Education/ training provided by government/ professional bodies	1	2	3	4	5
c) Education/ training provided by software/ hardware vendors	1	2	3	4	5
d) Information sharing among users	1	2	3	4	5
e) Low cost consultancy	1	2	3	4	5
f) Others	1	2	3	4	5

Q.8 Has your company implemented (MRP) systems? Please tick (/) the appropriate box.
Yes [ ] **No** [ ]
If yes, please go to Q.9 **If no, please go to Q.15**

Q.9 Which version of the following **MRP** systems versions has implemented in your company?
a. Material requirements planning **MRPI** ( )
b. **Closed-Loop MRP** ( )
c. Manufacturing resources planning **MRPII** ( )

Q.10 Listed below some common **MRP** systems definitions.
According to your opinion, please tick (/) where appropriate.
(a) Computerized materials/production planning and control system for production only ( )
(b) Primarily computerized materials/production planning and control system integrated with other business area to achieve a total business system ( )
(c) General system for computerizing any business function ( )
(d) Others ( )

Q.11 a) If you was asked to describe your company organizational arrangements for implementing MRP systems. Please check all statements that apply.
a) A steering committee was formed Yes ( ) No ( )
b) A steering committee met at least once a month. Yes ( ) No ( )
c) The project team generally met weekly. Yes ( ) No ( )
b) The project manager's only responsibility was managing the project.
Strongly disagree **Strongly agree**

1 2 3 4 5

Q.12 What was your major reasons for implementing an MRP system? Please tick (/) one score for each reason listed: **0 =Not at all 1= Weak reason 5= Strong reason**

a) Inventory control	0	1	2	3	4	5
b) Production control	0	1	2	3	4	5
c) Improve productivity	0	1	2	3	4	5
d) Lower inventory cost	0	1	2	3	4	5
e) Improve competitive position	0	1	2	3	4	5
f) Improve quality of products	0	1	2	3	4	5
g) Increase throughput	0	1	2	3	4	5
h) Meet delivery dates better	0	1	2	3	4	5
i) Others..	0	1	2	3	4	5

Q.13 Please indicate the degree of computerization of MRP modules.
0 for not at all, 1 for 1-20%, 2for 21-40%, 3 for 41-60%, 4 for 61-80%, 5 for 81-100%.
Please tick (/) <u>one</u> score for each MRP modules listed.

<u>MRP modules</u>						
a) Bills of materials	0	1	2	3	4	5
b) Inventory control	0	1	2	3	4	5
c).Master production Schedule	0	1	2	3	4	5
d) Capacity requirements planning	0	1	2	3	4	5
e) Forecasting	0	1	2	3	4	5
f) Purchasing and receiving	0	1	2	3	4	5
g) Shop floor control	0	1	2	3	4	5
H) Rough-cut capacity planning	0	1	2	3	4	5
I) Customer order service	0	1	2	3	4	5
j) Routing/work centres	0	1	2	3	4	5
k) Cost accounting	0	1	2	3	4	5
l) Financial analysis	0	1	2	3	4	5
m) Sales order processing	0	1	2	3	4	5
n) Operations scheduling	0	1	2	3	4	5
o) Material requirements planning (parts explosion)	0	1	2	3	4	5
p) Payroll/human resources	0	1	2	3	4	5

Q.14 Please indicate your company's organizational willingness to change:
...........Oppose change...........Resist change...........Suggest change...........Actively Seeks change

Q.15 If there are <u>not</u> any (MRP) systems has implemented in your company plan, please indicate:
a) The current system which is used..
b) How long this system has been used?. Please tick (/) where appropriate
a. Less than 3 years ( ) b. 3-5 years ( ) c. More than 5 years ( )
c) In your experience how significant are the following factors in influencing the company to favor the current system rather than the acquisition of MRP systems?
Please tick (/) <u>one</u> box for each factor listed.

	Of no significant	**Of some significant**	**Very significant**
1. Limited knowledge of MRP	[ ]	[ ]	[ ]
2. Not felt to achieve enough benefits	[ ]	[ ]	[ ]
3. Successful without using MRP	[ ]	[ ]	[ ]
4. Potential staff attitude problems	[ ]	[ ]	[ ]
5. Cost too high	[ ]	[ ]	[ ]
6. Not applicable	[ ]	[ ]	[ ]
7. Others:....................................	[ ]	[ ]	[ ]

Please, stop here and return the questionnaire.

<u>SECTION II</u> - Uncertainty determinants of MRP implementation.

The aim of this section is to explore the existing critical environmental uncertainty factors affecting MRP systems implementation in the Egyptian manufacturing industry.

Q.16 How important is each of the following uncertainty factors that might influence the implementation of MRP systems in your company. Please tick (/) <u>one</u> score for each factor listed. **1=Not important at all 5=Extremely important**

a) Product characteristics diversity	1	2	3	4	5
b) Amount of aggregate product demand	1	2	3	4	5
c) Machine downtime	1	2	3	4	5
d) The standard of raw material (quality)	1	2	3	4	5
e) Behaviour of people within the factory (e.g., absenteeism rate)	1	2	3	4	5
f) Reliability of plant within the factory walls	1	2	3	4	5
g) Capacity constraints	1	2	3	4	5

<u>SECTION III</u> - Implementational determinants of MRP implementation.

The aim of this section is to identify implementational determinants affecting **MRP** systems implementation in the Egyptian manufacturing industry.

Q.17 Which one of the following initiators played a major role in introducing MRP into your company?

a) Top management ( )
b) Production and inventory control (P&IC) management ( )
c) Both top management and P&IC management ( )
d) Data processing personnel ( )
e) Software/hardware vendors ( )
f) Others ....

Q.18 How long your MRP system has been used?. Please tick (/) where appropriate

a. Less than 1 years ( ) b. 1-2 years ( )
c. 3-5 years ( ) d. More than 5 years ( )

Q.19 Which implementation strategy was used:

.... Pilot .... Parallel .... Direct conversion .... Phased conversion

Q.20 Please indicate the importance of data accuracy of MRP system elements. Please tick (/) <u>one</u> score for each element listed **1= Little** **2 = Some** **3= Much** **4 = Very much**

a) Bill of material records	1	2	3	4
b) Inventory records	1	2	3	4
c) Shop floor control data	1	2	3	4
d) Capacity data	1	2	3	4
e) Market forecasts	1	2	3	4
f) Master production schedule	1	2	3	4
g) Vendor lead times	1	2	3	4
h) Production lead times	1	2	3	4
i) Routing/Work centre data	1	2	3	4

Q.21 The following set of statements deal with firms who used vendor supplied software. For those who developed MRP in house, please skip this question and Go to question 22. The following classifications are used: **1= Strongly Disagree** **5= Strongly Agree**

a) We expected more extensive vendor support	1	2	3	4	5
b) Vendor instructions understand their software product	1	2	3	4	5
c) We experienced a vendor software support discontinuation problem	1	2	3	4	5
d) The vendor provided conversion of our data into the new system	1	2	3	4	5
e) Vendor personnel efficiently resolved software problems	1	2	3	4	5

Q.22 To what degree have these obstacles or problems encountered MRP implementation within your company?. **1= weak problem** **5= strong problem**

.... A lack of support from top management
.... High cost of MRP system
.... Lack of support from production
.... Lack of support from supervisor/foreman
.... Lack of support from marketing
.... Lack of support from finance
.... Lack of clear goals for MRP effort
.... Lack of involvement from vendor
.... Poor training/education on MRP
.... Lack of suitability of hardware
.... Lack of suitability of software
.... Lack of company expertise in MRP
.... Lack of vendor knowledge on MRP
.... Lack of communication
.... Lack of information technology expertise

SECTION IV - Technological determinants of MRP implementation.

The aim of this section is to discover the main technological determinants of MRP systems implementation in the Egyptian manufacturing industry.

Q.23 Listed below are the most common features of MRP systems.
Please tick (/) one box for each feature listed.

a) Update method	.... Net change	.... Regenerative	.... Both
b) Use of cycle counting	.... Yes	.... No	
c) Use of pegging	.... Yes	.... No	
d) MPS update frequency	.... Weekly	.... Daily	.... Others
e) Allocation of inventory	.... Yes	.... No	
f) Use of automatic lot sizing	.... Yes	.... No	
g) Time bucket size	.... Weekly	.... Monthly	.... Others
h) Average number of weeks in MPS	....		

Q.24 a) Please indicate in which your company got MRP system
.... Developing the entire system in-house .... Buying turn-key system
b) Please indicate what computer hardware is your MRP system run on:
.... Microcomputers and mainframes ....Minicomputers
c) Where the maintenance of MRP is done? Please tick (/)where appropriate.
a. Done in-house ( )
b. Done by software vendor ( )
c. Done by IT specialists ( )

Q.25 The following categories are based on Oliver Wight's Class A, B, C or D companies. Which of these best describes the status of MRP in your facility? Please tick (/) where appropriate:
.Class A: A closed -loop system used for both priority planning and capacity planning. MPS is leveled and used by top management to the business. Most deliveries are on time, inventory is under control, and little or no expediting is done.
Class B: A closed-loop system with capability for both priority planning and capacity planning. In this case, the MPS is somewhat inflated, top management does not give full support, and some inventory reductions have been obtained, but capacity is sometimes exceeded, and some expediting is needed.
Class C: An order launching system with priority planning only. Capacity planning done informally, typically with an inflated MPS. Expediting is used to control the flow of work and a modest reduction in inventory is achieved.
Class D: The MRP system is 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.

Q.26 Please estimate how much your company had spent for the acquisition of an MRP system? Please tick (/) where appropriate
a) Less than L.E.300,000 b) L.E.300,000-599,999
c) L.E.600,000-899,999 d) L.E.900,000-1,199,999
e) L.E.1,200,000-1,499,999 f) L.E.1,500,000 or more than L.E.1,500,000

Q.27 a) Does there is an additional investment intended for MRP systems (hardware/software) over the next 3 years? .... Yes .... No
If Yes go to B If No, Please specify, Why?...
b) Please specify Why your company was prepared to further investment?
In order to extend the current MRP system ( )
In order to change the current system ( )
Others .... ( )
c) How much your company is prepared to further invest?
Please tick (/) where appropriate
a) Less than L.E.300,000 b) L.E.300,000-599,999
c) L.E.600,000-899,999 d) L.E.900,000-1,199,999
e) L.E.1,200,000-1,499,999 f) L.E.1,500,000 or more than L.E.1,500,000

Q.28 In this scale, 100 points means full integration among MRP modules. On the same scale, circle the number which indicates your actual degree of system integration:

0 10 20 30 40 50 60 70 80 90 100

SECTION V - Human determinants of MRP systems implementation.

The aim of this section is to explore the critical human determinants of MRP systems implementation in Egyptian manufacturing industry.

Q.29 To what extent do you utilize the outputs of an MRP system? Please tick (/) where appropriate.

a) Use daily [ ] b) Use weekly [ ] c) Use monthly [ ]

Q.30 a) What is your previous experience with automated, technically complex information systems before implementing an MRP system?

Very little	Somewhat	Moderate	High	Very High
1	2	3	4	5

b) What is your level of formal training? Please tick (/) where appropriate.

a) College graduate [ ]
b) Some college education [ ]
c) Technical school graduate [ ]
d) High school graduate [ ]
e) Less than high school [ ]

Q.31 What is your involvement in the implementation of an MRP system in your facility?

Please tick (/) where appropriate

a) Led Implementation [ ]
b) Active daily/weekly [ ]
c) Active monthly [ ]
d) Passive [ ]
e) Non-participant [ ]

Q.32 What level of support did you give to the decision to implement an MRP system?

Please tick (/) where appropriate

a) Total support [ ]
b) Very supportive [ ]
c) Supportive [ ]
d) Neutral [ ]
e) Opposed implementation [ ]

SECTION VI - MRP systems implementation success measures.

The aim of this section is to investigate the expected potential benefits of the MRP systems to explore the most appropriate criteria for measuring the performance of MRP systems in the Egyptian manufacturing companies.

Q.33 a) For each of the characteristics below (a-e) state (in column II) the current experience given your stage of MRP development. Then state (in column I) the experience that you would expect operating in today's economic environment with your pre-MRP production system. Finally, state (in column III) the future experience that you anticipate given total completion of your MRP development plans.

	I Pre-MRP Estimate	II Current Estimate	III Future Estimate
a) Inventory turnover			
b) Delivery lead time (days)			
c) Percent of time meeting delivery promises (%)			
d) Percent of orders requiring "splits" because of unavailable material (%)			
e) Number of expediters (number of people)			

b) To what degree have the following benefits been achieved from your MRP system?

	Degree of improvement			
	Little	Some	Much	Very Much
a) Improved competitive position	1	2	3	4
b) Reduced inventory costs	1	2	3	4
c) Increased throughput	1	2	3	4
d) Improved product quality	1	2	3	4
e) Improved productivity	1	2	3	4
f) Better ability to meet volume/ product change	1	2	3	4
g) Better production scheduling	1	2	3	4
h) Reduced safety stocks	1	2	3	4
i) Better cost estimation	1	2	3	4
j) Improved co-ordination with marketing and finance	1	2	3	4
k) Improved your ability to perform in your job	1	2	3	4
l) Reduced informal systemsfor materials management/ inventory/ production control	1	2	3	4
m) Increased BOM/inventory/MPS accuracy	1	2	3	4
n) Increased information on which to base	1	2	3	4
decisions since MRP has been implemented	1	2	3	4

Please if there are any factors influencing the implementation of MRP systems which you think are important and which have not been covered by the questionnaire, please use the space below to describe them. Any other comments about the questionnaire are most welcome.

Comments:

....

....

....

....

THANK YOU VERY MUCH FOR YOUR CO-OPERATION WHEN FINISHED, PLEASE REFOLD WITH THE PRE-PAID POSTAGE FACING OUT AND MAIL PROMPTLY

Appendix B

Table 5.3.1 Significant levels (P values) for the significant obstacles that impede the implementation of MRP systems by Non-MRP companies*.

Items	MRP Users K-W[a]	MRP Users ANOVA[a]
Limited knowledge about MRP	.18	.10
The successful without MRP implementation	.85	.88
Not applicable	.52	.54
Not felt to achieve big enough benefits	.17	.16
Cost too high	.74	.76
Potential staff attitude problems	.15	.15

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA).
[a] Significant at level .05.

Table 5.4. 1 Significant levels (P values) for the important factors in introducing MRP systems in Egypt*.

Items	Mann-Whitney	T-test
a) Government Support (e.g. grants, incentives)	.41	.26
b) Education/training provided by government	.65	.22
c) Education/training provided by software/hardware vendors	.42	.08
d) Information sharing among users	.64	.40
e) Low cost consultancy	.08	.06

* Using Mann-Whitney test and the T-test.
[a] Significant at level .05.

Table 5.5.1 Significant levels (T values) for the important reasons for MRP implementation in different contexts * (MRP users ratings).

Study	T value[a]
The current study versus Singapore study	1.07

* The Paired-T test for analysing the current V the Singapore study.
[a] Significant at (T=2.0).

Table 5.7. 1 Significant levels (P values) for the importance of data accuracy for MRP implementation scored by MRP users*.

Items	MRP Users K-W[a]	MRP Users ANOVA[a]
Bill of material record	.76	.78
Shop floor control data	.14	.20
Inventory records	.09	.07
Capacity data	.12	.14
Master production schedule	.60	.61
Market forecasts	.81	.83
Vendor lead times	.07	.06
Production lead times	.94	.95
Routing/workcentre data	.17	.17

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA) [a] Significant at level .05

Table 5.7. 2 Significant levels (T values) for data accuracy for MRP implementation in different contexts * (MRP users ratings).

Study	T value[a]
The current study versus the US study	2.27

* The Paired-T test for analysing the current V the US study.
[a] Significant at (T=2.0).

Table 5.7. 3 Significant levels (P values) for the importance of vendor support for implementing MRP systems scored by MRP users*.

Items	MRP Users K-W[a]	MRP Users ANOVA[a]
We expected more extensive vendor support	.76	.78
Vendor instructions understand their software product	.07	.07
The vendor provided conversion of our data into the new system	.31	.31
We experienced a vendor software support discontinue problem	.16	.15
Vendor personnel efficiently resolved software problems	.10	.09

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA).
[a] Significant at level .05.

Table 5.7. 4 Significant levels (T values) for vendor support in different contexts* (MRP users ratings).

Study	T value[a]
The current study versus the US study	11.23

* The Paired-T test for analysing the current V the US study.
[a] Significant at (T=2.0).

Table 5.7. 5 Significant levels (P values) for the critical implementation problems scored by MRP users*.

Items	MRP Users K-W[a]	MRP Users ANOVA[a]
Poor training/education on MRP	.32	.33
Lack of company expertise in MRP	.47	.48
Lack of support from production	.92	.93
Lack of support from supervisor/foreman	.27	.27
Lack of support from marketing	.40	.41
Lack of support from finance	.78	.79
Lack of clear goals for MRP effort	.20	.18
Lack of involvement from vendor	.88	.89
Lack of support from top management	.83	.84
Lack of suitability of hardware	.17	.16
Lack of suitability of software	.28	.29
High cost MRP system	.69	.70
Lack of vendor knowledge on MRP	.61	.63
Lack of communication	.46	.47
Lack of information technology expertise	.21	.23

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA) [a] Significant at level .05

Table 5.7. 6 Significant levels (T values) for critical implementation problems in different contexts* (MRP users ratings).

Study	T value[a]
The current study versus Singapore study	4.89

* The Paired-T test for analysing the current V the Singapore study.
[a] Significant at (T=2.0)

Table 5.8. 1 Significant levels (T values) for MRP system features in different contexts* (MRP users ratings).

Study	T value[a]
The current study versus Singapore study	1.27
The current study versus the US study	-.27
Singapore study versus the US study	-.95

* The Paired-T test for analysing the current V the US studies and the the Singapore study.
[a] Significant at (T=2.0)

Table 5.8. 2 Significant levels (P values) for the degree of computerisation of MRP modules in the individual industries * (MRP users ratings).

	MRP Users	
Items	K-W[a]	ANOVA[a]
a) Bills of materials	.87	.88
b) Inventory control	.08	.06
c).Master production Schedule	.19	.21
d) Capacity requirements planning	.59	.60
e) Forecasting	.19	.21
f) Purchasing and receiving	.59	.60
g) Shop floor control	.15	.14
H) Rough-cut capacity planning	.26	.26
I) Customer order service	.58	.59
j) Routing/work centres	.13	.06
k) Cost accounting	.11	.10
l) Financial analysis	.62	.78
m) Sales order processing	.71	.76
n) Operations scheduling	.10	.11
o) Material requirements planning (parts explosion)	.91	.91
p) Payroll/human resources	.21	.12

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA).
[a] Significant at level .05.

Table 5.8. 3 Significant levels (T values) for the degree of computerisation of MRP modules in different contexts* (MRP users ratings).

Study	T value[a]
The current study versus Singapore study	-1.08

* The Paired-T test for analysing the current the Singapore study.

[a] Significant at (T=2.0).

Table 5.9. 1 Significant levels (P values) for the previous experience with automated, technology complex information systems scored by MRP users*.

	MRP Users	
Items	K-W[a]	ANOVA[a]
The previous experience	.75	.74

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA)

[a] Significant at level .05

Appendix C

Table 6.2.1 Significant levels (P values*) for the improved performance in individual industries (MRP users ratings).

Item		Pre-MRP	Current-MRP	Future-MRP
a) Inventory turnover	K-W	.11	.06	.33
	ANOVA	.11	.06	.06
b) Delivery lead time (days)	K-W	.10	.11	.11
	ANOVA	.10	.17	.10
c) Percent of time meeting delivery	K-W	.77	.07	.74
promises (%)	ANOVA	.74	.08	.65
d) Percent of orders requiring "splits"	K-W	.00**	.48	.18
because of unavailable material (%)	ANOVA	.00**	.90	.40
e) Number of expediters (number of people)	K-W	.02**	.01**	.45
	ANOVA	.01**	.00**	.49

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA).
** Highly significant differences

Table 6.2.2 Significant levels (P values *) for the improved performance in the current study versus previous two studies (MRP users ratings).

Study	Pre- MRP estimate	Current-MRP estimate	Future- MRP estimate
Current versus Anderson	-.23	-.56	-.92
Current versus Laforge	.12	.28	.10
Laforge versus Anderson	.21	.37	.40

* Significant at .05 level (T=2.00)

Table 6.2.3 Significant levels (P values*) for the subjective benefits in MRP companies (MRP users ratings).

Item	K-W	ANOVA
a) Improved competitive position	.21	.21
b) Reduced inventory costs	.79	.80
c) Increased throughput	.93	.85
d) Improved product quality	.00**	.00**
e) Improved productivity	.62	.41
f) Better ability to meet volume/ product change	.00**	.00**
g) Better production scheduling	.82	.87
h) Reduced safety stocks	.06	.08
i) Better cost estimation	.34	.34
j) Improved co-ordination with marketing and finance	.53	.57
k) Improved your ability to perform in your job	.00**	.00**
l) Reduced informal systems for materials management/ inventory/ production control	.16	.22
m) Increased BOM accuracy	.13	.09
n) Increased information on which to base decisions since MRP has been implemented	.64	.66

* Using Kruskal Wallis and One Way Analysis of Variance (ANOVA)
** Highly significant differences

Table 6.2.4 Distribution of the subjective benefits by industrial sector scored by MRP users.

	Means				
Item	**PM s**	**MM s**	**ICM s**	**MS s**	**MIS s**
Improved product quality	2.0	2.3	2.0	2.4	2.4
Better ability to meet volume/ product change	2.0	1.9	2.1	3.2	2.2
Improved your ability to perform in your job	2.0	2.0	1.2	2.0	2.2

Table 6.2.5 Significant levels (P values*) for the subjective benefits of MRP implementation in the current study versus previous two studies (MRP users ratings).

Study	P value
Current versus Sum and Yang	-3.86
Current versus Schroeder	1.50
Sum and Yang versus Schroeder	13.58

* Significant at .05 level (T=2.00)

Appendix D

KMO Measure and Anti-image Correlation Matrix of MRP Benefits

----------- FACTOR ANALYSIS -----------

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .60042

Anti-image Correlation Matrix:

	VAR00218	VAR00219	VAR00220	VAR00221	VAR00222	VAR00225	VAR00226
VAR00218	.67619						
VAR00219	.10751	.51809					
VAR00220	-.03551	-.09754	.66346				
VAR00221	-.15817	-.02952	-.25710	.59563			
VAR00222	-.20847	.00740	.09388	.07867	.61494		
VAR00225	.22586	-.22207	.19658	-.20775	-.10404	.51172	
VAR00226	-.07812	-.10684	-.12279	-.15156	-.20759	.11446	.65762
VAR00227	-.00210	.08899	-.31299	-.19253	-.35036	.09251	-.01073
VAR00228	.02118	.05681	-.09861	.01753	.18416	-.19031	-.09181
VAR00229	-.04572	-.19343	.04139	-.15441	-.18273	.20182	.00409
VAR00230	-.12506	-.05567	.12000	.10228	-.05514	-.10551	.14083
VAR00231	.16052	-.02811	.05029	-.09135	-.16539	.20720	.24911
VAR00232	.09909	-.02200	.10510	-.05093	-.08272	.00716	.02798
VAR00233	.04085	-.18702	.00746	.05167	-.08954	.00065	.06605

	VAR00227	VAR00228	VAR00229	VAR00230	VAR00231	VAR00232	VAR00233
VAR00227	.56226						
VAR00228	.08386	.72321					
VAR00229	.35218	.22941	.55432				
VAR00230	-.10155	-.03649	-.10678	.52158			
VAR00231	.05287	.11034	-.05163	.06704	.50187		
VAR00232	-.07894	-.11339	.15448	-.03031	-.20583	.55753	
VAR00233	-.28324	.09001	-.20599	-.00503	.07843	.00181	.65326

KMO Measure and Anti-image Correlation Matrix of Uncertainty Factors

....FACTOR ANALYSIS...

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .60823

Anti-image Correlation Matrix:

	VAR00029	VAR00030	VAR00031	VAR00032	VAR00033	VAR00034	VAR00035
VAR00029	.60105						
VAR00030	-.11932	.53164					
VAR00031	-.21731	.13542	.64385				
VAR00032	.15853	-.08511	.20160	.68629			
VAR00033	-.01274	-.07738	-.18935	.07195	.61643		
VAR00034	.13450	.18418	-.02902	.12192	.10124	.51434	
VAR00035	-.05672	.24117	.00789	.13647	-.25206	.06923	.59686

KMO Measure and Anti-image Correlation Matrix of Data Accuracy Factors

....FACTOR ANALYSIS..

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .60547

Anti-image Correlation Matrix:

	VAR00108	VAR00109	VAR00110	VAR00111	VAR00112	VAR00113	VAR00114
VAR00108	.60123						
VAR00109	-.12662	.55116					
VAR00110	-.02598	.17847	.51074				
VAR00111	-.01933	-.10476	-.06135	.60947			
VAR00112	-.27925	-.28998	-.23271	.04428	.55738		
VAR00113	.04941	-.03501	-.04981	.17020	-.03002	.52544	
VAR00114	-.17310	.08327	.07846	-.35210	.00078	-.19087	.64548
VAR00115	-.00172	.09267	.13807	-.24698	.04478	-.14539	-.13765
VAR00116	.00935	.15144	-.00342	.19898	-.22118	.24992	.00435

	VAR00115	VAR00116
VAR00115	.74007	
VAR00116	.12240	.65470

KMO Measure and Anti-image Correlation Matrix of Vendor Support Factors

....FACTOR ANALYSIS...

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .60122

Anti-image Correlation Matrix:

	VAR00121	VAR00123	VAR00124	VAR00125	VAR00128	VAR00130
VAR00121	.66820					
VAR00123	-.10358	.58183				
VAR00124	-.40228	-.21309	.61550			
VAR00125	.24098	.08742	.16225	.74492		
VAR00128	-.21604	-.14949	.01195	-.10845	.53760	
VAR00130	-.04762	-.49261	.24168	.04604	.12137	.52396

KMO Measure and Anti-image Correlation Matrix of MRP Problems

....FACTOR ANALYSIS..

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = .60136

Anti-image Correlation Matrix:

	VAR00143	VAR00145	VAR00147	VAR00149	VAR00150	VAR00151	VAR00152
VAR00143	.63883						
VAR00145	-.25239	.63937					
VAR00147	-.02164	.11306	.63539				
VAR00149	.07821	.19048	.16799	.62005			
VAR00150	.16333	.14269	.11935	-.17829	.62622		
VAR00151	.15153	-.24978	.04344	-.11356	-.12958	.56947	
VAR00152	-.43531	-.06936	-.08239	-.11150	-.06720	-.17988	.60895
VAR00153	-.14477	.26607	-.11800	.08948	-.21884	.06861	.19384
VAR00146	.00393	-.12153	.03045	.00156	.03729	.00663	-.04890
VAR00154	-.09941	-.03095	.01134	-.24243	.23455	-.08564	-.14420
VAR00155	.11435	-.03906	.20853	.07042	.15399	.08197	-.02959
VAR00156	.16854	-.05338	-.03743	-.13767	.02957	.13431	.08563
VAR00141	-.06854	.32760	-.15346	.13592	-.32568	.01069	-.20165
VAR00144	.09248	.23971	.03602	-.11399	.15529	-.25725	-.07201

	VAR00153	VAR00146	VAR00154	VAR00155	VAR00156	VAR00141	VAR00144
VAR00153	.55752						
VAR00146	.02569	.55481					
VAR00154	-.07639	-.02687	.60614				
VAR00155	-.02892	.14826	-.04279	.67961			
VAR00156	-.18189	-.35674	-.17558	.32446	.57267		
VAR00141	.17134	-.24233	.09137	.06219	.12493	.57268	
VAR00144	.25955	.15352	.20008	-.00055	-.31803	.06049	.52559

Discussion of the extracted factors from the Principal Components of Factor Analysis

(1) The five extracted factors from the subjective benefits are discussed below:

Factor one: Operational efficiency

Two subjective benefits measures out of fourteen loaded very significantly in this factor all above .50 as it is illustrated in Table 7.4 (Chapter .7). Since all these subjective benefits measures calls for increasing efficiency, it is named "Operational Efficiency".

Factor two: Co-ordination

This factor is loaded with two subjective benefits measures which accounted 14.1% of the total variance. Since "improved co-ordination with marketing and finance" has the highest loading, it affects the label of the factor (Hair et al., 1992). Therefore this factor is labelled "Co-ordination"

Factor three: Manufacturing Planning & Control (predictability)

This factor is identified by the high significant loadings of two subjective benefits measures which accounted for 10.0% of the total variance. Because of "better production scheduling", and "reduced safety stocks" are reflected in better manufacturing planning and control, this factor is interpreted and labelled "Manufacturing Planning and Control".

Factor four: Formal system

This factor is identified by the high significant loadings of two subjective benefits measures which accounted for 9.8% of the total variance. These are concerned with "reduced informal systems for materials management/ inventory/ production control" and "increased BOM/inventory/MPS data accuracy". Therefore, this factor is interpreted and labelled "Business Results".

Factor five: Inventory costs

This factor is identified by the high significant loadings of one subjective benefits measure which accounted for 8.5% of the total variance. Since this benefit measure deals with "reduced inventory costs", this factor is named "Inventory Costs".

(2) The twenty extracted factors from determinant variables are discussed below:

Uncertainty constructed factors:

Factor one: The required products

Three variables out of seven loaded significantly in this factor all above .70 as it is illustrated in Table 7.5 (Chapter .7). Since all these uncertainty variables relating to products, it is named "The Required Products".

Factor two: Capacity

This factor is loaded with two uncertainty variables which accounted 19.1% of the total variance. Since "capacity constraints" and "machine downtime" are concerned with production capacity. Therefore, this factor is labelled " Capacity".

Factor three: Reliability

This factor is identified by high significant loadings of two uncertainty variables which accounted for 14.6% of the total variance. Since "reliability of plant within the factory" has the highest loading, the label of this factor is "Reliability".

Implementation problems constructed factors:

Factor four: Technical

Three implementation problems are loaded highly in this factor and accounted 18.6% of the total variance. These problems call for technical issues. Thus, this factor is interpreted and labelled "Technical".

Factor five: Management support

This factor includes three implementation problems which accounted for 14.6% of the total variance. These are concerned with lack of support from top management, production management and marketing management. Therefore, this factor is interpreted and labelled "Management Support".

Factor six: MRP expertise

Two implementation problems included in this factor which accounted for 12.9% of the total variance. Since the second variable has the highest loading, it influence the label of the factor (Hair et al., 1992). Thus, this factor is interpreted and labelled "MRP Expertise".

Factor seven: People support

This factor is identified by two implementation problems which accounted for 11.7% of the total variance. Because of the high loading of the lack of support from supervisor/ foreman, this factor is interpreted and labelled " People Support".

Factor eight: Active vendor support

Only one implementation problem is loaded in this factor. It is accounted for 7.6% of the total variance. Since this calls for the vendors involvement where they are regularly going to the companies to know how does system work, what are the implementation problems and to provide the advice through meeting or training programmes, it is named "Active Vendor Support".

<u>Organizational & Technological & Human constructed factors:</u>

Factor nine: Company size

This factor is identified by three organisational variables which accounted for 21.2% of the total variance. These are "gross sales"; "number of P & I C employees"; and "number of items per product". Since all of them call for determining company size, this factor is named "Company Size".

Factor ten: Stage of development

This factor includes two technological variables which accounted for 14.9% of the total variance. These are concerned with the development of MRP implementation achieved by MRP users. Therefore, this factor is labelled " Stage of Development".

Factor eleven: Experience

This factor is identified by one human variable which accounted for 10.7% of the total variance. Since this variable calls for the degree of previous experience with the automated information systems, it is named "Experience".

Factor twelve: BOM level

Only one organisational variable is loaded in this factor. It is accounted for 8.4% of the total variance. Since this variable calls for the number of bill of materials, it is labelled "BOM Levels".

Factor thirteen: Company maturity

This factor is identified by one organisational variable which accounted for 7.9% of the total variance. Since company age is a constructed factor identified by the length of company in operation, it is named " Company Maturity"

***Vendor support constructed factors*:**

Factor fourteen: Vendor support availability

Two variables are loaded in this factor and accounted for 35.8% of the total variance. Since these variables indicate the degree to which the vendors are available to call them to turn up to solve the implementation problems, this factor is named "Vendor Support Availability".

Factor fifteen: Active vendor proficiency

This factor includes two variables which explained 21.7% of the total variance, making the cumulative percentage of variance over 70.0%. Vendor support variables in this factor indicate into the degree of proficiency to offer the instructions of their software product which is easy understood by the user, and also indicate the vendor proficiency to solve software problems. Therefore, this factor is labelled " Active Vendor Proficiency".

Factor sixteen: Vendor experience

This factor is loaded with only one variable which accounted for 16.7% of the total variance. Since this variable calls for the vendor experience to help MRP user to convert their data to be available with MRP systems such as coding data, using spreadsheets...etc. Thus, this factor is interpreted and called "Vendor Experience".

__Data accuracy constructed factors:__

Factor seventeen: Supply planning data

Three data accuracy elements are loaded in this factor and accounted for 24.3% of the total variance. These elements deal with the issue of planning based on supply data such as capacity data, vendor lead times and production lead times. Therefore, this factor is interpreted and labelled "Supply Planning Data".

Factor eighteen: Demand planning data

This factor includes three data accuracy elements which accounted for 17.7% of the total variance. These are concerned with planning based demand data such as BOM records, inventory records and market forecasts. Thus, this factor is named "Demand Planning Data".

Factor nineteen: Schedule execution data

This factor is identified by two data accuracy elements which accounted for 11.8% of the total variance. These are concerned with scheduling and routing/ work centre data. Since the first element has the highest loading, it influences the label of the factor. Thus, this factor is labelled "Schedule Execution Data".

Factor twenty: Operating execution data

Only one element of data accuracy elements is loaded in this factor. It is accounted for 11.5% of the total variance. Since this element calls for increasing the accuracy of the required data to perform job, it is named " Operating Execution Data".

Appendix E

ACE Example

The example below illustrates the key advantage of ACE over standard regression techniques. This example also address the interpretation of an ACE model. It demonstrates the effectiveness of ACE by attempting to recover the transformations for individual variables in the following equation used to construct Y:

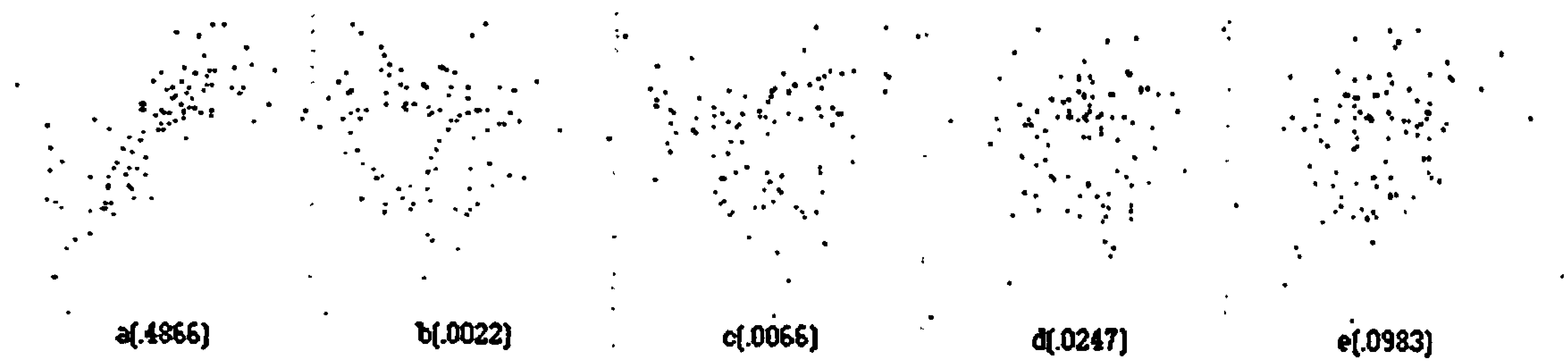
$$Y = \log[3\sin(1.3A) + \text{abs}(B) + C^2 + (D^3 / 9) + E + 10] - 8 \qquad (1)$$

where A, B, C, D and E are independent samples of 100 observations drawn from the Normal distribution with mean 0 and variance 1. Note that relationship (1) above can be re-expressed as:

$$e^{8}\exp(Y) = 3\sin(1.3A) + \text{abs}(B) + C^2 + (D^3 / 9) + E + 10 \qquad (2)$$

Thus, if we are simply given the data values for Y, A, B, C, D and E, without knowledge of functional relationship (1), we might try to plot Y individually against the independent variables A, B, C, D and E so as to gain some insights on the pair-wise relationships, yielding the graphs in Figure 1.

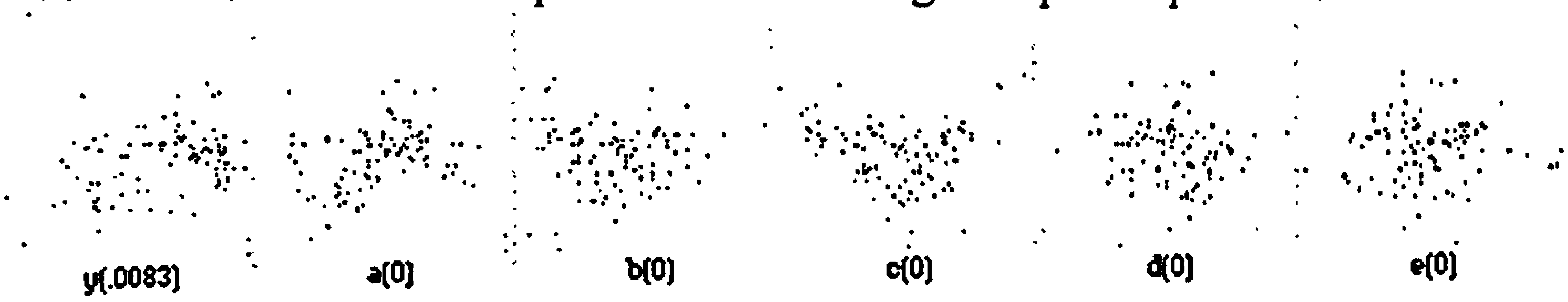
Note that the plots in Figure 1 do not suggest any obvious transformation for either the dependent or independent variables.



Y vs. X's
Figure 1

Ordinary Regression:

If we then regress Y on A, B, C, D and E using Ordinary Least Squares (OLS), we will obtain an R^2 of 0.637. We might plot the residuals from the regression first against the fit $\hat{Y}$, then separately against the independent variables to see if there might be patterns to suggest possible transformations for the independent variables. The plots are shown in Figure 2. Perhaps only the plots of the residuals versus A and C gives any hint that some non-linear component of A or C might help to explain the variation in Y.



Residuals Plots
Figure 2

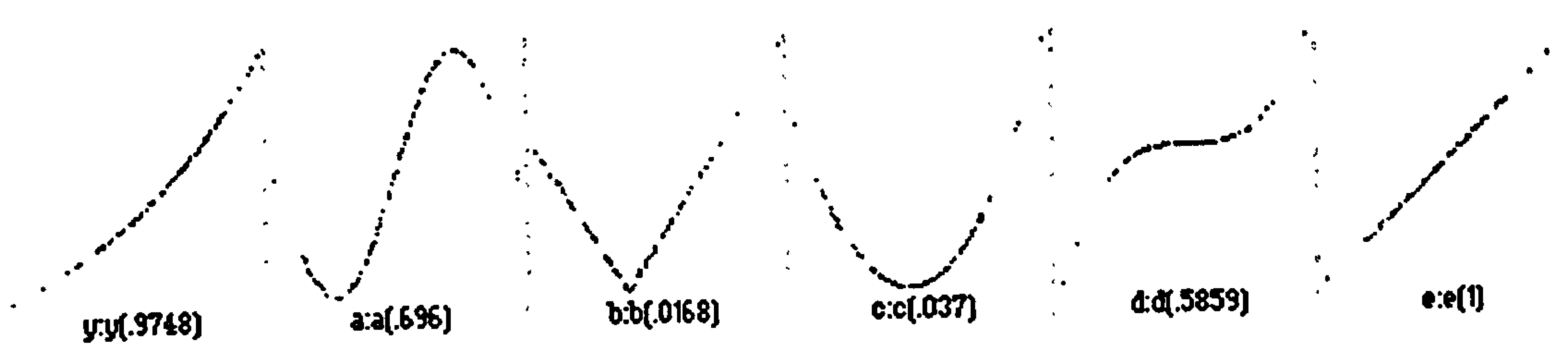
ACE Regression:

If we now invoke ACE on the given data set, ACE will provide an output of individual transformations for the variables as shown in Figure 3. ACE's suggested graphical transformations for the variables are shaped like exponential for Y, sine for A, absolute-value for B, square for C, cubic for D, and linear for E, which are exactly the corresponding functions in relationship (1).

ACE Transformations
Figure 3

Note that the transformations do not provide any information on the scales of the transformed variables (e.g., 3 for sin(1.3A)) or any shift in the origins for the transformed variables (which would affect the intercept +10). This is because the scaling of an independent variable does not affect the fit of the corresponding regression model, and any translational shift in the origins will be absorbed into the constant term in a regression. We therefore need not be concerned with the markings on the scale for the ordinate (y-) axis in a plot of the suggested ACE transformation for a variable. That is, the origin for the y-axis can be fixed anywhere and the unit of measurement for the y-axis is arbitrary. In addition, the suggested ACE transformations are constructed such that a larger transformed value for an independent variable will be associated, everything else being equal, with a larger value of the transformed dependent variable. In other words, if we regress the transformed dependent variable on all the transformed independent variables, all parameter coefficients for the independent variables will be positive. Since we are fitting a model to the data and because ACE's suggested transformations (Figure 3) are in graphical form, we would, at this point, need to look for analytic functions that approximate the suggested ACE transformations for transforming the original data. In this example, we would arrive quite easily at analytic functions such as exponential for Y, sine for 1.3A (the 1.3 would be estimated from the observed x-values at the turning points on the transformation plot for A), absolute-value for B, square for C, cubic for D, and no transformation for E (Figure 4). After we have applied these analytic functions to transform the original data, a regression of the transformed Y on the transformed independent variables will obviously produce an R^2 of 1, an intercept of $10e^{-8}$, and parameter coefficients of $3e^{-8}$, e^{-8}, e^{-8}, $e^{-8}/9$ and e^{-8} for the corresponding independent variables. The functional relationship of the model in Figure 4 is thus:

$$E[\exp(Y)] = 3e^{-8}\sin(1.3A) + e^{-8}\text{abs}(B) + e^{-8}C^2 + e^{-8}(D^3/9) + e^{-8}E + 10e^{-8} \tag{3}$$



Analytic Transformations
Figure 4

In actuality, the ACE model has an R^2 of 0.997 which is short of 1.0 because ACE, being a numerical procedure, is not perfect even on an analytic model. However, note that the R^2 of 0.997 is considerably better than 0.637 as obtained using OLS. It is important to note that in theory ACE can not fit worse than ordinary regression, because if no transformation is indeed necessary (i.e., the ordinary regression model is exactly true), then ACE would simply suggest nearly linear transformations for all variables (much like the transformation for E in Figure 3).

Naturally, ACE will generally not do as well as the example here when (1) some independent variables are highly correlated, (2) there is an error term, (3) some independent variables are omitted or (4) some extra independent variables are present, although this last situation is partially taken care of by a built-in stepwise variables selection procedure.

Interpreting ACE Transformation Plots:

To study the effects of the independent variables (A, B, C, D, E) on the dependent variable (Y), we can refer to relationship (3) or the analytic ACE transformation plots (Figure 4). In general, it is easier to interpret the ACE model from the transformation plots because the plots are easier to conceptualise compared to the mathematical expressions of the transformations which can be quite cumbersome. If we choose to interpret using transformation plots, then a very useful observation to note is that when the transformation for the dependent variable is an increasing function, then the transformed scores (y-axis) of the individual transformation plots of the independent variables are positive correlates of the observed (i.e. pre-transformed) score for the dependent variable. This observation is true because a higher transformed score for an independent variable has a larger contribution to the transformed score of the dependent variable (because the corresponding parameter estimate for the independent variable is always positive), which in turn maps back onto a higher observed score for the dependent variable (because its transformation is an increasing function).

Similarly, a lower transformed score for an independent variable has a smaller contribution to the transformed score for the dependent variable, which in turn maps inversely onto a lower observed score for the dependent variable. In this example, the transformation for Y is an increasing function (i.e., exponential) (Figure 4) and the parameter estimates for A, B, C, D, and E are positive (see relationship (3)), hence a higher transformed score for B, say, will result, everything else being equal, in a higher transformed Y score, which in turn translates back into a higher observed Y score. In short, a higher transformed B score will map onto a higher observed Y score, and vice versa. Therefore, when we want to relate the independent variables (A, B, C, D, E) to the dependent variable, Y, we can bypass the mapping onto the Y transformation plot, and simply regard the transformed scores of the independent variable plots as positive correlates of the observed Y scores. In other words, we can, for interpretation purposes, treat a transformed axis (y-axis) of an X-variable transformation plot as if it were the observed (pre-transformed) axis (x-axis) of Y, provided the ACE transformation for Y is an increasing function.

So we only need to focus on the individual transformation plots of the independent variables in order to study their effects on the dependent variable, Y. For instance, if we look at the transformation plot for A (Figure 4), we know that the ACE model suggests that, as the observed A score increases, the observed Y score would decrease, then increase, and then decrease again. As for B, its absolute-value transformation suggests that as B increases, Y would decrease and then increase (Figure 4).

Generating an ACE Model:

The ACE module produces an output of graphical transformations for the dependent and independent variables. ACE will also indicate the adjusted and imputed p-value of the model based on these graphical transformations (all p-values are really only the computational counterparts of the p-values in a standard regression model, but they are useful for between-model comparisons as well as for variables selection). As the transformations for this preliminary ACE model are presented in graphical rather than analytic form, analytic functions will then have to be constructed to replace the ACE transformations for transforming the original data (see De Veaux ("Finding Transformations for Regression Using the ACE Algorithm." Sociological Methods & Research, vol 18, 1989) for examples of analytic function construction). Ordinary Least Squares regression can then be applied to the transformed data to arrive at the final ACE model.

To ensure that the analytic functions represent the graphical ACE transformations adequately, the adjusted in the preliminary and the final ACE models must be checked for a close match. The statistical significance of the variables in the final model are then ascertained, and the model assumptions of constant variance and normality checked.