Effective Use of MRP-Type Computer Systems to Support Manufacturing

by

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(ABSTRACT)

Within the last 30 years, Manufacturing Resource Planning (MRP-type) computer systems have quickly evolved from basic materials requirement planning software to today's enterprise resource planning (ERP) integrated software packages that reside on client/server computer architecture. However, given the magnitude of influence these computer systems encompass, very little research has been conducted to monitor and improve how companies are actually using these MRP, advanced MRP and ERP computer systems. In practical terms, where is the typical manufacturing organization today in terms of MRP systems development? To what extent is software being applied for use in enterprise integration?

A survey study of manufacturing companies in Virginia and Tennessee was conducted to evaluate the current use and performance of computer systems to support manufacturing applications. This study explores the reasons why organizations chose to use these systems, the problems and benefits derived from the MRP/ERP systems, and the characteristics of the types of companies that have benefited from the use of MRP-type systems. The survey participants evaluated the performance of their manufacturing or enterprise planning systems on the basis of data accuracy, customer satisfaction, user satisfaction, systems effectiveness, convenience, information relevance, and software reliability. Furthermore, success factors associated with organizational performance were tested and evaluated. The correlation between perceived performance was tested against the influence of upper management support, the level of emphasis on training, sources of technical expertise, and organizational experience with MRP-type systems.

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Chapter 1
Introduction and Scope of Research

1.1. Introduction

Computer systems to support manufacturing business processes have become widespread throughout manufacturing industries over the last thirty years. During this time the computer systems to support manufacturing resource planning have quickly evolved from basic materials requirement planning (MRP) software to today's sophisticated extended enterprise integration packages that reside on client/server computer architecture. The popularity of MRP-type systems is demonstrated by the many companies that have acquired manufacturing resource planning or "MRP II" systems (Anderson, Schroeder, Tupy, and White, 1982; Chase and Aquilano, 1995). In 1996, the Institute of Industrial Engineers published a list of 94 MRP software vendors (MRP II Software, 1996). Yet despite the rapid development of MRP software, very little work has been done to monitor how companies are actually using MRP II (Sum & Yang, 1992).

The purpose of this research is to evaluate the current use of computer systems to support manufacturing applications in industry today: to what extent software is being used in enterprise integration, the benefits derived from using MRP-II and ERP systems, and the characteristics of the types of companies that have benefited from the use of MRP applications. Furthermore, success factors associated with organizational performance are evaluated and validated. The correlation between perceived performance is evaluated against the influence of upper management support, the level of organizational emphasis on training, sources of technical expertise, and organizational experience with MRP-type systems.

1.2. The System Addressed

Though the system to be addressed in this research centers around the existing Manufacturing Resource Planning computer technology, it also includes the operators, those who provide the input data, the users, the organizational structure and management system within which it operates, and any other elements that influence the effectiveness of the manufacturing computer support system. MRP II computer systems are developed by nearly a hundred vendors (IIE Solutions, 1996) and quite possibly may not be identified within a company as a "MRP II" system. For example, MIS managers in many electronic manufacturing plants consider "ERP" or enterprise resource planning the new trend for manufacturing computer support systems. In 1997, it is still common to find manufacturing companies operating MRP systems on IBM AS400 minicomputers or other centralized data processing hardware systems. Many organizations are in the process of implementing enterprise resource planning computer systems on client/server network systems.

Regardless of whether the system is developed in-house or leased from a vendor, for the purpose of this study a computer system qualifies as the type of system to be addressed if

it performs the following functions:

> Inventory management, product data management, location/lot management, capacity requirements and materials requirement planning, and, to some degree, accounts receivable, accounts payable, and sales analysis.

The computer system in this study is defined by the application in which it is used. While a wide range of software and hardware is available to support manufacturing production, this study focuses on the integration of computer technology within the organizational system. Inevitably, "the system" must include the operators, the users, the management structure, and any other elements that influence the effectiveness of the computer system to support the performance of the organization.

While most companies today use MRP-II or ERP computer systems for supporting manufacturing functions, this study will loosely refer to these computer systems as "MRP-type" or simply "MRP" systems.

1.3. Background

As organizations continue to seek ways to improve their overall performance, and new computer technology pressures industry to update and overhaul information systems, computer applications to support manufacturing have developed rapidly in recent years. Relatively simple materials requirement planning systems were first introduced in the 1960s. As the capabilities of computer technology continued to increase, more modules were added to integrate other organizational/business functions into manufacturing-support computer systems. These computer systems are more commonly known as manufacturing resource planning or MRP II. Today, some companies are upgrading and maintaining their current MRP II systems while others are installing new client/server networks within their organization. The most common of the new MRP-type software is generally known as ERP, or Enterprise Resource Planning. These computer systems require a large financial investment as well as organizational commitment in training, changing processes, and adapting to the new technology.

The widespread use of computers in industry today presents a need for developing increased knowledge of how to effectively apply manufacturing resource planning, client/server systems, and computer applications in general. Quite often, computer applications change the way work is performed. Industrial engineers have traditionally been involved in "the design, improvement, and installation of integrated systems" which link people, materials, information, equipment and energy (Hodson, 1992). Within the field of industrial engineering, computers have long been used as decision making tools, but the overwhelming influence and potential of computer applications and computer support systems present a broad area in which knowledge of productivity and performance factors need to be developed.

1.4. Research Interest

Some practical research questions to investigate are as follows:
What issues and problems have companies encountered in the implementation of MRP systems?

What issues should be evaluated to insure its effective integration within the operations of an organization?

How can potential problems be minimized in implementing complex new technology into the existing structure of an organization?

What must be considered from the organizational as well as the technical perspective in order to most effectively integrate the technology and people in the organization who use it?

Although this study cannot fully answer these questions, this research will provide valuable information concerning the technological and management systems used to support manufacturing organizations. Evaluation of implementation and problem issues will serve to further support management decision making.

1.5. Research Questions

There is a wide range of conflicting perspectives regarding the usefulness of MRP-II systems, and popular literature provides many negative accounts describing the limitations and inaccuracies of existing MRP-II systems. Because of this, it can be assumed that these computer systems are not being used to the limits of their potential as cited in academic literature and industry publications. (Chamberlain and Thomas, 1995; Goddard, 1994). However, there has been little research conducted to determine how MRP-II systems are currently being used. Several sources cite barriers that are common causes of problems in MRP implementation (see section 2.3.1). Given the results of previous studies and the findings of this survey study, this research will identify the characteristics of MRP-type systems used in today's manufacturing industries. Furthermore, the study will test for correlations between system performance and user training techniques, determinants of success in outsourcing for technical expertise, and the effects of upper management support from the operational perspective.

The results of this survey will provide additional practical information for organizations seeking to implement MRP-II or ERP systems, providing recommendations pertaining to the issues that must be addressed for companies to avoid critical problems in their own implementation of MRP-type systems. Previous studies have demonstrated that MRP systems are more widespread in larger companies that engage in complicated manufacturing processes than in companies with simpler continuous flow processes (Anderson *et al.*, 1981; Sum & Yang, 1993). The lack of technical expertise and personnel

training needs were identified as the major problems facing MRP implementers (Sum & Yang, 1993, DeLone, 1988). The need for top management support is frequently cited as a critical success factor in effective MRP-type system implementation (DeLone,1988; Correll,1995; Martin,1995).

Questions to address:

What type of manufacturing organizations are using Manufacturing Resource Planning in industry today?

How are MRP systems currently being used? Which specific operations is MRP software currently supporting?

Is the involvement of computer and technical consultants a determinant of the successful implementation and performance of MRP computer systems?

Is upper management support critical to the success of MRP systems?

Is the success of a computer system dependent upon the level at which employee training is emphasized ?

The results of this survey will provide organizations with additional information with which to address critical issues in MRP-type systems implementation.

The generalized question to which this research will contribute is: What are the basic factors that determine the success of MRP-type computer systems implementation in regards to the ability of the system to impact organizational performance? When an organization decides to adopt and integrate an extended, inter-departmental computer system into its operations, what issues must be addressed to insure that the computer application system will effectively contribute to organizational performance improvement?

1.6. Research Approach

A survey of individuals involved with the management of MRP-type systems was conducted in order to obtain relevant data for this study. The survey population sample was developed primarily from the membership lists of local APICS and IIE chapters in central and western Virginia, and eastern Tennessee. In order to obtain demographic information about organizations using MRP-type systems, only one questionnaire was sent to each company. More information about the methodology of the study is detailed in Chapter 3.

1.7. Research Objectives

The objectives of this research are as follows:

1. To independently obtain up-to-date information regarding the state of MRP systems in industries today.
2. To survey current users about factors that contribute to the effectiveness of their MRP-type computer systems, especially in regards to sources of technical expertise, user training techniques, and the effect of upper management support. This will serve to validate previous research as well as obtain more information about successful experiences in industry.
3. To determine if the perceived performance of MRP-type computer systems can be correlated with the degree of management support, the use of external consultants, the method of user training, and the length of time MRP systems have been used.

1.8. Research Hypotheses

The research hypotheses to be tested in this study are as follows:

Hypothesis 1: Most manufacturing organizations today are struggling to make effective use of computer technology but, the reality is that only a fraction of their production functions have been computerized.

Hypothesis 2: Performance of MRP-type systems is based upon the level of **upper management support**, including upper management involvement, initiation of the MRP/ERP system implementation, and knowledge of the computer system.

Hypothesis 3: Performance of MRP systems is dependent upon **the level to which the software package is customized for an organization**

Hypothesis 4: The **length of time** that an organization has used MRP-type systems is a determinant of MRP performance.

Hypothesis 5: The performance of MRP-type computer systems is dependent upon higher levels of computer **training for employees**.

Hypothesis 6: Companies that have implemented **a quality or productivity improvement program** such as TQM have better performing MRP systems than companies that do not have such a program.

The methods by which these hypotheses will be tested are described in section 3.4 - 3.6.

Chapter 2
Background

This section reviews the development of Materials Requirements Planning (MRP) and Manufacturing Resource Planning (MRP II) computer application systems in industry. Previous research, particularly survey studies related to MRP and computer applications to support manufacturing, are also summarized.

2.1. The Development of Manufacturing Resource Planning

Definitions

MRP-I **M**aterials **R**equirement **P**lanning**,** a computer-based system for managing inventory and production schedules. This approach to materials management applies to large job-shop situations in which many products are manufactured in periodic lots in several processing steps. It does not apply to continuos-flow-type manufacturing systems. (Bedworth & Bailey, 1987)

MRP-II **M**anufacturing **R**esource **P**lanning, a system in which the entire production environment is evaluated to allow master schedules to be adjusted and created based on feedback from current production/purchase conditions. (Bedworth & Bailey, 1987)

Materials Requirements Planning (MRP, or MRP-I) was launched in the mid-1960s and quickly became popular for providing a logical, easily understood method for determining the number of parts, components, and materials needed for the assembly of each end item in production. As computer power grew and demands for software applications increased, MRP systems evolved to consider other resources besides materials. Software modules were added to include functions such as scheduling, inventory control, finance, accounting, and accounts payable.

As the materials requirements planning systems matured in the 1970s and 1980s, other portions of the productive system were naturally added to the computer software system. One of the first functions to be included was purchasing. The software modules were expanded to handle cost data and selling price capabilities. Additional data about work center capacity limitations were also integrated into many systems as detailed scheduling for the shop floor was provided by the MRP systems. It was quickly becoming obvious that "*material requirements planning"* no longer was adequate to describe the expanded system. Oliver Wight is credited for introducing the name *"manufacturing resource planning-MRP II"* to reflect the idea that a larger part of the firm was becoming involved with the program. (Wight, 1981)

"The initial intent for MRP II was to plan and monitor all the resources of a manufacturing firm--manufacturing, marketing, finance, and engineering -- through a closed-loop system generating financial figures." (Chase & Aquilano, 1995, 609) MRP II was also

intended as a way to simulate the manufacturing system. The idea of the closed-loop system indicate that once the MRP program produce a initial production schedule, the output data is then sent to departments such as sales and operations to verify that the plans are realistic and attainable. Ideally, not only are many functions included in the output system, there is also feedback provided by the execution functions so that the planning can be kept valid at all times.

"For more than a decade, efforts continued in MRP II systems along the lines of adding some modules and making continuing small improvements. The basic system and its operating logic remained intact. IBM's Manufacturing Accounting and Production Information Control System (MAPICS), for example contains 19 interrelated modules." (Chase & Aquilano, 1995, 609) This is one of many MRP II systems that is still widely used.

The software modules included in the MAPICS system are listed below:

Accounts payable
Accounts receivable
Capacity requirements planning
Cross-application support
Data collection system support
Financial analysis
Forecasting
General ledger
Inventory management
Inventory management for process
Location/lot management
Master production scheduling planning
Material requirement planning
Order entry and invoicing
Payroll
Product data management
Production control and costing.
Purchasing
Sales analysis

2.2. MRP Functions, The Purpose of MRP Systems

According to Chase and Aquilano (1995), MRP computer systems serves the organization by providing the functions below:

In terms of Inventory, MRP systems:

1) Determine the number of parts, components, and materials needed to produce each end item.
2) Determine the right part, right quantity, & right time to order parts. Provide time schedules for ordering materials & parts.
3) Maintain a bill of materials sequencing the assembly parts of the final product ("*schematic, product structure tree*").

Priorities: Order for the right due date, keep the due date valid.

Capacity: Plan to optimize the use of plant & equipment capacity
Plan an accurate load.

Theme of MRP (Chase & Aquilano, 1995):

"Getting the right materials to the right place at the right time."

Objectives: (from Chase/ Aquilano, 1995)

MRP has the same objectives as any inventory management system

1. To improve customer service
2. Minimize inventory investment
3. Maximize production operating efficiency

Philosophy of Material Requirements Planning:

The materials should be expedited (hurried) when their lack would delay the overall production schedule and de-expedited (delayed) when the schedule falls behind and postpones their need.

According to Chase/ Aquilano (1995), the information provided by MRP systems allow firms to realize the following benefits:

Ability to price more competitively
Reduce sales price
Reduce inventory
Better customer service
Better response to market demands
Ability to change the master schedule.
Reduce setup and tear-down costs
Reduced idle time.

In addition to these benefits, MRP systems also

Gives advance notice so managers can see the planned schedule before actual release orders.
Tell when to de-expedite as well as expedite.
Delays or cancels orders.
Changes order quantities.
Advances or delays order due dates.
Aids capacity planning.

2.3. General Perspective of Today's MRP systems

A few reference excerpts:

"To the great surprise of many, manufacturing resource planning (MRP II) is still the dominant application software for today's manufacturing management" (Turbide, 1995, 28).

"From a technical standpoint, the acceptance of new computing concepts and advanced architectures has turned the MRP II software industry and its user community upside down,..." M.R. Rangaswami (quoted by Teresko, 1994, 56).

"It's fifteen years later and MRP II still keeps on going. Keeping it alive, however, isn't the only goal. The only issue that counts is running a business more effectively. When a more productive planning process comes along, MRP II will fade away - just like any other great tools of the trade" (Goddard, 1994, 40).

"MRP II concepts, or closed-loop manufacturing systems, reached their zenith during the late 1970s and 1980s" (Martin, 1995, 31).

"Today, manufacturing is reevaluating departmentally oriented MRP II products in an attempt to plan and develop the next generation of enterprise oriented manufacturing solutions. In response, some MRP II vendors are scrambling to distribute modules of older software onto PCs and workstations, while others contemplate a strategic redesign of their products" (Teresko, 1994, 53).

"Many firms claimed as much as 40 percent reductions in inventory investment due to conversions to MRP systems" (Chase/Aquilano, 1995, 595). Although there are over 300 MRP II software systems on the market (IIE Solutions, 1995, 7: 36-41), popular literature cite conflicting opinions regarding the effectiveness of these systems. MRP is technically well developed and implementation should be straightforward. Yet there are many problems with MRP systems and many "failures" cited in installing the systems. Why do such problems and outright failures occur with such a "proven," developed system?

2.3.1. Problems with MRP implementation

Many sources state that problems associated with MRP systems lie, to some degree, with organizational and behavioral factors (Turbide, 1995; Chase & Aquilano, 1995). Among the causes cited for MRP system failures are the following:

1) Lack of top management commitment - "Part of the blame for the lack of top management commitment may be MRP's image. It sounds like a manufacturing system rather than a business plan. However, an MRP system is used to plan resources and develop schedules. Also, a well-functioning schedule can use the firm's assets effectively, thus increasing profits. MRP should be accepted by top management as a planning tool with specific reference to profit results" (Chase & Aquilano, 1995, 595). Executives must be educated on the use of MRP as an integrated, strategic planning tool.

2) Failure to recognize that MRP is only a software tool that needs to be used correctly to adapt the organization and its processes to exploit the system's capabilities. "...MRP proponents overdid themselves in selling the concept. MRP was presented and perceived as a complete and standalone system to run a firm, rather than as part of the total system" (Chase & Aquilano, 1995, 596).

3) Insufficient user training and education - In nearly every study conducted and in many published cases, the lack of training or understanding is considered a major barrier to MRP implementation. DeLone notes that lack of understanding about computers is frequently cited as a reason for failure of small business endeavors (Raysman, 1981). In their study, Sum and Yang (1993) identified that the lack of MRP expertise, training, and education were major problems facing MRP implementers. There are several published books about user training for Management Information Systems. The need to adapt employees to their MRP systems definitely exists.

4) Lack of technical expertise - Not only is there a need to improve user training techniques and general understanding of MRP systems, there is also a definite lack of technical expertise to provide the leadership needed to implement the systems. Not only would the technical experts need to be familiar with the operational needs of daily production, the system integrators would also need to understand how the computer software system can be built to handle the production needs. Increasingly, the advanced MRP-type systems are seeking to integrate concepts of Just-In-Time (JIT) production into the computer applications system.

Sum and Yang (1993) found "Lack of company expertise in MRP" to be the major implementation obstacle, followed closely by "Lack of training/experience on MRP." DeLone (1988) suggested that the use of external programming could compensate for the lack of technical expertise. However, in his study he found that the use of external programming is not associated with computer success in small companies. Rather, he suggests, success is more dependent on the ability of top management to direct and manage external computer expertise rather than the level of involvement of external computer experts.

5) MRP requires a high degree of accuracy for operation. This often requires changing how the company operates and how files are updated. Traditionally, production management allowed for plenty of excess buffer stock to be stored on site. The extra inventory stores allowed for differences between the recorded inventory and actual inventory. One of the aims of the MRP system is to minimize inventory, thus the accuracy of the recorded levels becomes critical. Engineering drawings and bills of materials must also be kept up-to-date if the MRP system is to function correctly.

"Perhaps one of the biggest complaints by users is that MRP is too rigid. When MRP develops a schedule, it is quite difficult to veer away from the schedule if need arises" (Chase & Aquilano, 1995, 596).

2.3.2. The Shortcomings of MRP-II Systems

" Since the 1970s, MRP has grown from its purpose of determining simple time schedules, to its present advanced types that can theoretically together all major functions of an organization. During its growth and its application, MRP's disadvantages as a scheduling mechanism have been well recognized. This is largely because MRP tries to do too much in light of the dynamic, often jumpy system in which it is trying to operate" (Chase & Aquilano, 1995, 596).

MRP-II systems do not allow actual material, time and capacity requirements to be determined until the system plans an actual lot size for a given run. In essence, the traditional systems cannot determine what products to build until the manufacturer receives an actual order specifying the required unique combination of parts. It is not uncommon for material schedulers force "dummy orders" into computer production systems in order to minimize production inaccuracies due to inaccurate, forecasted demand. In today's competitive marketplace, business is won by suppliers who can quickly meet customer orders. At times material schedulers will find that in order to start a production run without an actual order in hand, an estimate of an anticipated production order can be placed into the computer system that would meet the necessary checkpoints that the are built into the software. Because MRP systems may not been tailored to meet the needs of "Just-In-Time" production, schedulers may choose to overlook the computer system or "manipulate" it to accommodate priority customers who has specific needs and deadlines to be met.

The inaccuracy of the bill of materials and inventory database is a common problem with MRP systems. Inaccurate bills of materials mean inaccurate material and capacity plans. Providing a management system that will facilitate data accuracy will likely require major adjustments in strategic management approaches (Correll, 1995).

2.3.3. Advanced MRP-Type Systems or Software changes from MRP II to ERP(Enterprise Resource Planning)

For more than two decades, firms focused at the plant production level chose MRP systems to handle product demand, inventory levels, inventory order quantities, resource availability and production schedules. Since the mid-1980s industries have found themselves competing to meet product demands from a global marketplace; increasing subcontracting of products and parts; and managing more distributed, multiple-plant sites, both domestic as well as international sites. "In today's environment, MRP users want instant access to information on customers' needs, which plants can meet these needs, and company wide inventory levels and available capacity" (Chase & Aquilano, 1995). Rather than relying on historical data to predict inventory and sales levels, more efficient, more effective service could be provided by instantaneously accessing the latest data from inventory and sales figures on remote databases.

As industries find plant and organizational sites becoming more distributed, the capabilities of client-server architecture will be further developed. "From a technical standpoint, the acceptance of new computing concepts and advanced architectures has turned the MRP II software industry and its user community upside down,..." (M.R. Rangaswami, quoted by Teresko, 1994). While many vendors are selling and maintaining existing MRP systems, others are developing new advanced systems based on MRP logic. Accordingly, while some firms are modifying their current software programs, others are developing systems with major changes in the basic software programming logic and database structure.

"Today, manufacturing is reevaluating departmentally oriented MRP II products in an attempt to plan and develop the next generation of enterprise oriented manufacturing solutions. In response, some MRP II vendors are scrambling to distribute modules of older software onto PCs and workstations, while others contemplate a strategic redesign of their products" (Teresko, 1994). Various names have been given to these advanced MRP-type systems. The Gartner Group introduced *Enterprise Resource Planning* (ERP) and Advanced Manufacturing Research (AMR) introduced a similar software, *Customer-Oriented Manufacturing Management Systems* (COMMS).

Advanced MRP systems are recognized for their databases and interdepartmental linkages. Their structure provide a natural basis for MRP systems to become an enterprise integration tool. Enterprise integration is viewed as developing the availability and accessibility of information within an extended corporate system and using the information system to effectively coordinate both the decisions and actions of thousands of individuals (Enterprise Integration Laboratory, Univ. of Toronto, 1994).

To fully operate in an enterprise sense, there needs to be distributed applications for planning, scheduling, costing, and so on to accommodate the multiple layers of the organization, its work centers, sites, divisions, and management levels. Multiple languages and currencies are also being included for global applications (Chase & Aquilano, 1995). Advanced MRP systems (also called ERP or next-generation MRP II) will include the following (Greene, 1992) :

Client/server architecture.
Relational database with SQL.
Graphical user interface.
Multiple database support.
Front-end systems for decision support.
Automated Electronic Data Interchange (EDI) - for better communications with customers and suppliers.
Interoperability with multiple platforms.
Standard application programming interfaces.

2.4. Distributed MRP Processing versus Centralized Processing

Many companies have invested significant capital into MRP systems that reside on mainframe computers and centralized processing or "legacy" computer systems. In order to provide users throughout the firm with reliable, real-time information, relational databases are being implemented on mainframe systems. Oracle Corp. has a widely used relational database system and fourth-generation language that is being incorporated to enhance existing MRP systems. Sequent Computers Systems, for example, is using Oracle's manufacturing software on its computer (Chase & Aquilano, 1995).

When using a mainframe computer hardware system, or centralized process operation, software features to support engineering, production scheduling, forecasting, order processing, purchasing, and materials planning are controlled at one central location, even if the system is used to control multiple plant sites. For different plant sites, a decentralized processing operation distributes the computer information processing responsibilities among the plants. A distributed processing operation uses a combination of centralized and decentralized controls to allocate resources where they are logically needed and where they can be executed most efficiently (Costello, 1992). A popular concept supporting distributed computer systems is that shifting to global manufacturing will encourage more decentralized MRP to allow more local control. However, the management and maintenance needs of distributed computer systems should not be underestimated. Distributed, client/server computer systems may allow for customization and information processing at the client site, but this architecture also introduces higher levels of system complexity and more complex control issues.

The cost of client/server systems is far higher than managers expected. The tools and technologies for client/server systems have not fully evolved, and the need for implementation planning and personnel training were often underestimated (Rifkin, 1994). Early adopters of client/server technology found that the relative ease of developing client/server applications allowed them to build many applications using a wide mix of tools without much thought to the long-term overall results (Rick Martin, 1995). Later adopters are being more cautious, explicitly addressing architectural issues and standardization early in the process.

2.5. Future Enterprise Integration Trends and SAP Systems

In manufacturing, client/server systems have the potential of providing essential data sharing between design engineers, production engineers, purchasing, the stockroom, and the factory floor. While the promise of open systems in manufacturing has yet to be realized, many of the systems are "in their infancy in terms of functionality" (Booker, 1994). In applications development, formalizing consistency for screen views would be difficult considering each department has its own functional data requirements and "view" of the product. Client/server technology does suggest the likelihood that, in the future, a repair technician will be able to use a single identifier, e.g. a serial number, to query manufacturing, engineering, and customer databases. A simple serial number for a part could access a database to provide the date of

production, component part information, part suppliers, and a history of engineered design changes for the product. Such a tool would be invaluable for customer service and for troubleshooting mechanical problems.

The need for enterprise integration tools is demonstrated by the current trend popularizing SAP R/3 software systems in large US corporations. SAP provides a software system that accommodates enterprise resource planning (Smith, 1996). Using a client/server network to access on-line databases, software systems such as SAP could easily replace traditional Materials Resource Planning (MRP) systems.

In the early 1990s, ***Systeme, Prodokte in der Datenverabeitung*** (German for **Systems, Applications, and Products in Data Processing**) a.k.a. **SAP AG Corporation**, introduced their R/3 system to the U.S. market. SAP R/3 provides an extensive spectrum of integrated business applications on client/server distributed systems. The package runs on most versions of UNIX, Windows NT, IBM OS/2, Dec VMS, and Hewlett Packard MPE/IX, and supports a large variety of databases including Oracle, Informix, DB2, and Microsoft SQL Sever 6.

In addition to traditional business computing functions such as financial accounting and asset management, the SAP R/3 system integrates modules in production planning, materials management, sales and distribution, business workflow, human resources, and plant maintenance. The ability of the SAP systems is still being tested in the United States, but SAP's development agreement with Microsoft and Intel exemplifies the potential clout of this software system. Because of SAP's adaptability to different types of industries, the software requires involved customization for each organization. Influential development of this client/server software can be expected in the future.

Many companies are justifiably reluctant to invest the capital required to install drastically new systems. Rather than adopting the R/3 package, many firms have installed SAP's earlier R/2 system that runs mostly on IBM 370 mainframe computers. As of 1994, SAP's R/2 system was used by more than 2,300 customers.

Traditional production companies such as Steelcase and Cadbury are already using SAP R/3 for their enterprise resource planning (Smith, 1996). Consulting companies such as Price Waterhouse and Anderson Consulting are heavily involved in implementing SAP systems. Other companies currently implementing SAP include Proctor and Gamble, Apple Computers, General Motors, and Intel (RWD, Inc. webpage, [http://www.rwd.com/]).

Client/server systems provide a tool to assist in re-engineering business processes. In today's fast paced business environment, instant access to information is increasingly becoming a requirement to remaining competitive in the marketplace. Though the evolution of client/server software has not yet reached maturity, many organizations have already realized significant system improvements using client/server networks. Client/server systems will not only be an invaluable tool for future process improvement efforts, it is likely to be the "essential enabler" for large scale increases in organizational productivity.

2.6. The Enterprise Client/Server Model

From an organizational perspective, client/server architecture provides a model for extended enterprise integration. The technological capability of the system allows independent computers to be linked to the organizational network, enabling efficient communications to other client users and different databases. This network system has the ability to link products from different server types, whether the client uses IBM-PC, Macintosh, or Unix operating systems. The information access linkages also connect databases from different server types.

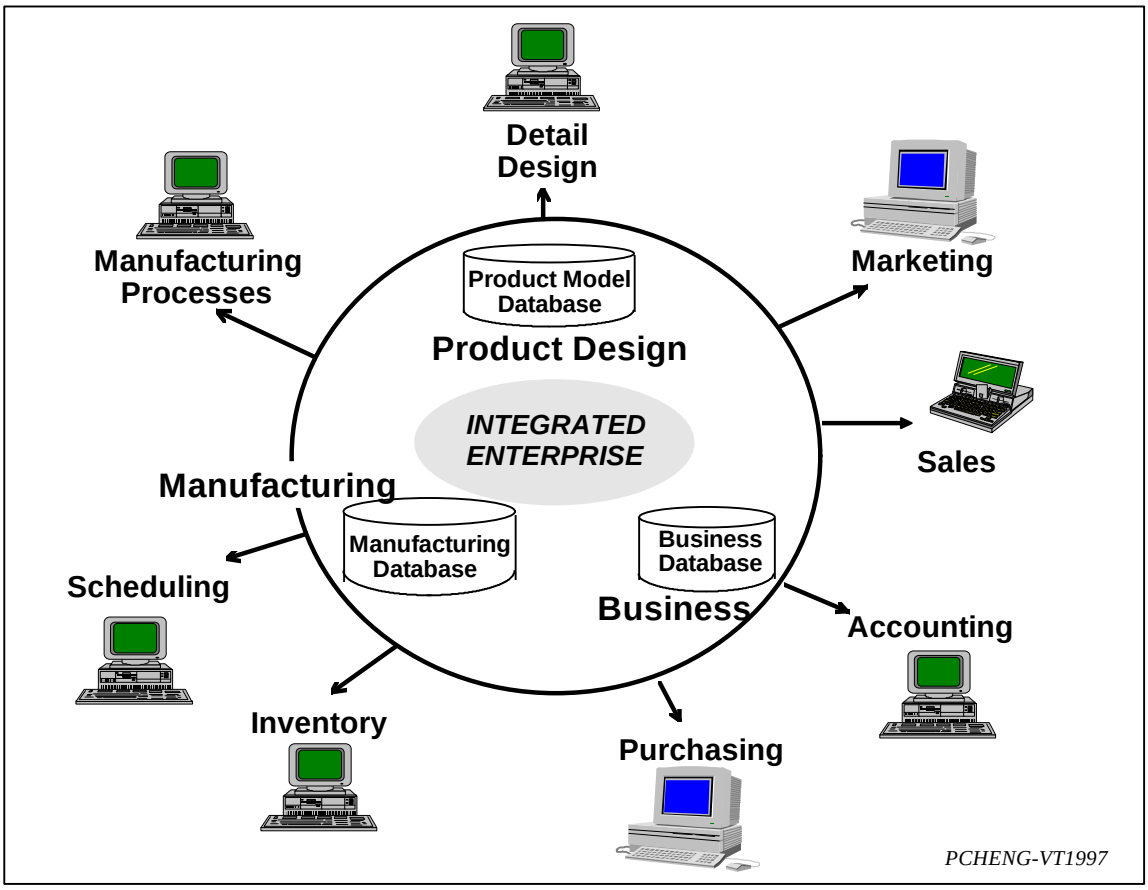


Figure 1. **The Enterprise Client/Server Model**

In a production oriented organization, the extended enterprise client/server system links the departments involved in each phase of the product development process. Typically, product information will be initiated in marketing and design groups. The data can then be linked to the accounting department, manufacturing, the component purchasing group, the inventory control function, and production schedulers. This extended enterprise

network links traditionally segmented organizational functions, allowing them to share data and customize information in a form that would be most useful for other internal customers in the organization.

In addition to linking functional departments, this model client/server system can also link employees in distant locations. The manufacturing and inventory groups within a large corporation are commonly located remotely from the design engineering group. Thus, a integrated enterprise client/server system allows a mechanism for data coordination and accessible data sharing between these functional departments. Ideally, information from the design engineering group can also be shared with marketing, thus providing a inter-connected matrix organization with a networked computerized system that allows for feedback at every stage.

This concept of this integrated enterprise client/server model is used in the structure of advanced MRP and enterprise resource planning computer software. Enterprise resource planning software packages such as SAP have gained immense popularity in recent years. The enterprise client/server model provides a theoretical structure for applying client/server systems to encompass extended organizational - enterprise changes. In industry today many companies are working towards the integration of network systems, yet few organizations have developed client/server systems that have been integrated to this extent in the organization.

2.7. Previous Studies Used in Survey Development

The studies reviewed below were used as a basis for the development of the survey distributed to industrial respondents.

2.7.1. *Materials Requirements Planning Systems: The State of the Art*

Anderson JC, **Schroeder** RG, **Tupy** SE, and **White** EM, "Material Requirements Planning systems: the state of the art," ***Production Inventory Management***, 1982, vol. 23, no.4, pp. 51-66.

"This article reports on an extensive survey of 679 APICS (American Production and Inventory Control Society) members, Material Managers and Production Inventory Control Managers, regarding the use of Material Requirements Planning Systems. The study is the largest survey of MRP Practice ever taken." Funded by APICS Educational and Research Foundation, the study describes (1981) findings of the nature of MRP systems in practice, the extent of growth of MRP, the role of computerization, and the benefits achieved in practice.

According to Anderson *et al.* (1982), "Material requirements planning (MRP) systems have been the target of thoughtful speculation on the part of managers not having MRP systems, the source of stability and discipline for managers who have MRP systems, and the subject of much presentation and discussion in literature. It is generally felt that MRP systems, when properly implemented, can be a tremendous asset to management." They go on to say, "Remarkably, little has been done to observe the state of the art of MRP systems from a wider perspective. Most information that is available today comes from personal observation and remarks from active consultants in the field."

A six page survey was developed which included questions to identify the nature of the company involved, the current status of the MRP system, the benefits and costs incurred, the nature of implementation problems and implementation approaches used. Based upon a pilot study, the questionnaire took about 45 minutes of the manager's time to complete. The survey questionnaires were sent out to 1, 700 APICS members in APICS Regions III and V, including North Dakota, South Dakota, New York, Pennsylvania, and West Virginia. Care was taken to ensure that only one questionnaire was sent for each firm represented.

Of the 1,700 firms represented, 679 or 40 percent of the sample population responded. Of those 679 companies reporting, 433 (or 64%) indicated that they had MRP systems in place or in some stage of development. Of the companies responding, the profile of sales volume reported ranged from under $10 million to over $100 million in sales.

A wide variety of industries were represented in the study. The greatest representation came from the electronic, instrument, fabricated metals, machinery, transportation industries and other manufacturing industries. Electric-electronic instrument, transportation equipment, and miscellaneous manufacturing industries appear to be the most highly committed to using MRP. Other industries, such as lumber and wood, paper, apparel, petroleum and coal, were less involved with MRP. One conclusion that could be drawn is that as the process becomes more complex, there appears to be a higher commitment toward the use of MRP.

Similarly, the commitment to using MRP increases as the size of the firm increases. The size of the firm was measured by sales volume, the number of parts and components, and by the number of employees. There was 43% reported MRP usage for companies with sales less than $10 million per year, while 70% of the companies with sales greater than $100 million had MRP systems.

Oliver Wight's definition of Class A through D users describe both the broad and narrow perspectives of MRP. A modified definition of these classes were used in the study.

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

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

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

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

"A company's definition of MRP becomes broader as they mature toward a Class A user. Over 60 percent of the firms reporting MRP usage identify themselves as Class C or Class D users. Only 38 or 9.5% of the firms reporting MRP usage claim to be Class A users (1981).

Anderson *et al.* (1982) found that the growth rate of MRP system developments is remarkable. The design of the MRP system varies widely in terms of definition and features incorporated into the systems. Substantial improvements have been realized in several critical performance measures including inventory turnover, delivery leadtime, delivery promises, and order splitting. Material managers are optimistic regarding further improvements.

2.7.2. *A Study on Manufacturing Resource Planning (MRP II) Practices in Singapore*

Sum, C-C., and **Yang**, K-K., "A Study on Manufacturing Resource Planning (MRP II) Practices in Singapore," ***Omega***, March 1993, v.21, n.2, p.187 (11).

This 1991 study, sponsored by the National University of Singapore, extensively surveyed manufacturing companies in Singapore that have adopted MRP II systems for improving their business operations. The survey investigated application practices, costs and benefits obtained, and the implementation process in MRP companies.

This study was patterned after the Anderson *et al.* (1982) survey. Typical titles of respondents included Materials Manager, Production and Inventory Control Manager, Master Scheduler, MIS Manager, and Production Manager. The questionnaire was sent to approximately 750 companies, 128 of which responded, from which 59 had implemented MRP. Of the industries represented, the largest representation of MRP companies was from electronic products and components, fabricated metal products, and the electrical machinery,

apparatus, and supplies industries. MRP was found to be more prevalent in older companies with more complex manufacturing processes and operations.

It was found that as a company increased in size as measured by gross sales, it was more likely to adopt MRP. Only 18.4% of companies with less than S$ 10 million (Singapore dollars) used MRP while 83.3% of companies with sales between S$200 and S$500 million had adopted MRP.

About half (49.2%) of the MRP systems resided on minicomputers while microcomputers and mainframes each accounted for 20.3% of the hardware platforms. A majority of the companies (71.1%) sourced their MRP software from vendors. Only 13.6% of the companies developed the entire software in-house.

The extent to which companies had implemented MRP was measured by the degree to which modules had been computerized. The most highly computerized modules were bill of materials, inventory stock control, and materials requirements planning. Sixteen modules were evaluated on the degree of computerization using a six-point Likert scale. ('0' for 'not at all', '1' for '1-20%', to '5' for '81-100%').

The understanding of the term "MRP" was also evaluated using the participants' choice of definitions of the term MRP. Rather than identifying MRP as a general system for computerizing any business function, or a computerized planning and control system for production only, 67.2% of the survey participants identified MRP as a "primarily computerized materials/production planning and control system integrated with other business areas to achieve a total business system."

Information pertaining to the total hardware and software investment in MRP was collected and summarized. The results suggested that there are two major groups of users. "The first group comprises of smaller users who had spent between S$100,000 and S$300,000 (US $141K to $423K) while the other group of larger users had spent more than S$500,000 (US $705K)." The smaller systems belonged to small and medium enterprises while the larger systems are owned by multi-national corporations and larger enterprises. "The additional system investment is more evenly spread among the different types of enterprises, indicating that the smaller companies were prepared to further invest large amounts in their MRP systems."

Major MRP benefits and reasons for implementation were ranked on a 5 point Likert scale. Benefits such as better delivery, better responses to changes, and better scheduling generally matched reasons for implementation. Reasons were primarily operational in nature. It appears that companies intend to apply MRP as a tool for improving operational efficiency rather than as a means for increasing competitiveness.

Sum & Yang noted that top management in Singapore plays a major role in introducing MRP to their companies. The study showed that 67.8% of the Singapore companies cited top management as the MRP initiator while only 18% of the US companies cited top management as their MRP initiator. Lack of MRP expertise, training, and education were identified as major problems facing MRP implementers. Surprisingly, they found that cost was not a major barrier to MRP implementation.

The authors suggest that "Case studies could be carried out to better understand the complexities of the implementation process and to study how companies cope with organizational changes that accompany MRP adoption. More research needs to be conducted to discover how companies could use MRP to compete better."

2.7.3. *Determinants of Success for Computer Usage in Small Business*

DeLone, W.H. "Determinants of Success for Computer Usage in Small Business," MIS Quarterly, March 1988, pp. 51-61.

This study approaches MIS success from the perspective of small businesses. It attempts to develop a measure of success for small businesses. Other studies that had been published prior to its 1988 publication date typically focused on large computer systems, ignoring differences in organizational size. An impressive literature review is included. The study focused on manufacturing firms with less than 300 employees. This study is significant with the trend of increased power/decreased cost of hardware and software for small businesses.

According to DeLone, "Lack of computer knowledge on the part of the owner/manager and lack of computer experience have resulted in all too many misadventures in electronic data processing (Scholhammer and Kuriloff, 1979). Small businesses are financially ill-equipped to absorb such expensive mistakes (Cohn, T. and Lindberg, 1972). ...Computers, if managed properly, can contribute to the success of small businesses operations, but the risks are significant. Guidelines for the successful application of computers are needed."

DeLone cites two measures of successful computer-based information systems (CBIS) that are appropriate for small businesses: (1) Management use of the information system, and (2) The impact of the information system on organizational performance. (Delone, p.52) He subsequently chose to measure (1) the actual use of computer-generated reports by top management, and (2) the impact that the computer applications are having on the business.

Small businesses typically lack specialized knowledge and technical expertise. Lack of understanding about computers is a frequently cited reason for failure of small business

computer endeavors. (Raysman, 1981) There are factors that will help compensate for this lack of knowledge. Top management involvement (Newpeck & Hallbauer, 1981), company-supported training (Bevis, 1979; Weber & Tiemeyer, 1981), and the use of external computer expertise (Briggs, 1980; Couger and Wergin, 1974; Greenwood, 1981) can improve the chance of successful computer use by small firms.

DeLone selected the following success factors (independent variables) for his study:

1. the use of external programming support
2. the level of computer based information system planning
3. top management knowledge of computers
4. top management involvement in computerization
5. personnel acceptance of computers
6. the sophistication of computer controls
7. the age of computer operations
8. the level of computer training
9. the type of computer use.

Ninety-three (93 of 191) small manufacturing firms in Los Angeles participated in the survey, the average size of the firms (all less than 300 employees) was 62 employees, and the average annual sales revenue was $5 million (firms with less than $30 million in annual sales revenues were targeted). "These firms had been using computers for an average of 48 months with an average of 5 different computer applications. They spent an average of $4,120 per month on their computer operations, a figure equal to nearly 1 percent of their sales revenue."

Two questionnaires were developed. Both were mailed out to the company's chief executive officer. The "Chief Executive Questionnaire," was to be completed by the company's top executive. "It included questions about the success of the firm's computer-based MIS and items related to computer understanding and experience." The second questionnaire wa.s to be completed by the employees who was "administratively responsible for the company's computer processing."

Results:

Surprisingly this study found that ***the use of external programming is not associated with computer success,*** despite strong literature documentation to support otherwise. DeLone hypothesized that small manufacturing firms realize a higher level of computer based information systems success with greater use of external computer expertise. DeLone concludes that "External computer expertise is no substitute for chief executive knowledge," particularly in small companies, where the chief executive officer must be involved in decisions as to which systems should be computerized. DeLone suggested that instead of the level of involvement of external computer experts, the determinant of success is more likely found in the chief executive's ability to direct and manage external computer expertise.

Top management involvement is positively associated with success.
The ***CEO's involvement in computer operations is associated with the success of computer operations***.
Length of computer use is not associated with success.

Surprisingly, ***greater levels of employee acceptance were not associated with higher levels of CBIS (Computer Based Information Systems) success***.
"A minimum level of employee acceptance is prerequisite for any level of success, but levels of acceptance higher than a threshold value do not necessarily generate higher levels of success." Only 16 of the 93 firms sampled had poor or fair acceptance levels. The low number of cases in these categories reduced the power of the statistical tests.

Also, ***the level of computer training for employees is not associated with success***.
"Only 29 of 93 responding firms engaged in formal training. This also reduced the power of the statistical tests. Formal training alone did not result in greater CBIS success. Presumably the key computer personnel in the 64 firms without formal training acquired the necessary computer skills before they were hired or through informal on-the-job training - such as one employee showing another how to execute a specific task."

Comments on DeLone's research hypotheses

Hypothesis: Small manufacturing firms realize a higher level of CBIS (computer-based information system) success when they have:

H1: **greater use of external programming support**
Given DeLone's results, the hypothesis should probably be rephrased or tested in a different manner

H3: **a chief executive with greater computer knowledge**
H4: **a chief executive who is more deeply involved in the computerization of applications**
These two hypotheses appear to be interdependent. Testing this would serve to further re-inforce a generally accepted and proven hypothesis.

H7: **use their computers for a longer period of time**
According to this study, the period of time that a computer system is used is not a determinant of the success of the system. Should the length of time that an organization uses computer systems serve to increase their level of technical expertise?

H8: **higher levels of computer training for their employees**
This study does not investigate training methods in detail, though it indicates that formal in-house training does affect success outcomes. There is a need to further

investigate the effect of training on MRP systems performance.

H9: **on-site computers (vs. use of computer services)**

From this study it is unclear how off-site computer services in manufacturing organizations are used. Within manufacturing, where will the MRP II hardware system reside? Does the company have a department that administers the hardware and software? How does the organizational structure and the physical location of the computer system affect employee perceptions and the success of the system?

2.7.4. *The State of EDI in the U.S. Housewares Manufacturing Industry*

Zack, Michael H., "The State of EDI in the U.S. Housewares Manufacturing Industry," ***Journal of Systems Management***, December 1994, vol. 45., no. 12, pp. 6-10.

"A survey was mailed to 400 of the approximately 2000 members of the National Housewares Manufacturers Association asking them about their use of EDI (Electronic Data Interchange). Specifically, they were asked to indicate for today and in three years which EDI transactions they were using with their customers (retailers) and suppliers, the number of customer and supplier EDI trading partners and the sales volume transacted via EDI. They were asked to evaluate the major influences on implementing EDI and, if they were not using EDI, to identify perceived barriers and future EDI plans."

Of the 400 surveys distributed, 193 usable questionnaires were returned, representing an unusually high 48% response rate. Of those responding, 69% were using EDI, 31% were not. Only 7 manufacturers (5% of the companies using EDI) indicated they were doing EDI with suppliers, and with only an average of 3.4 suppliers each.

M.H. Zack found that basic purchase orders and invoice were the most popular transactions being processed using EDI. Overall, manufacturers are using EDI with a few trading partners and the number of retail EDI partners is expected to remain a function of company size. The most important influence on a manufacturer's decision to implement EDI was pressure from their key retail customers. Large retailers such as Wal-Mart, K-Mart, Target, and J.C. Penney are leading the push to EDI.

While this study does not directly address Manufacturing Resource Planning, the survey technique and the results of the study are worth noting. According to John Harhen, "Emerging standards activity in the area of EDI will play an important role in facilitating the interconnection of the MRP system of one company with those of its suppliers" (Harhen, 1988, 32). Although previous MRP studies indicate that few firms have developed MRP computer systems to handle sales order processing, advanced MRP-type systems currently being developed include software modules to integrate sales analysis, order entry and

invoicing, accounting functions, and location or lot managment. Undoubtedly, future MRP-type computer systems will include electronic data interchange capability integrated in a database system that links order processing with manufacturing production. The growth of such cross-application support is stimulated by the characteristic capabilities of client-server computer systems.

2.7.5. *Evaluating Information System Effectiveness*

Hamilton, S., **Chervany**, N.L. "Evaluating Information System Effectiveness -- Part 1: Comparing Evaluation Approaches," ***MIS Quarterly*** September 1981, pp 55-69.

This article provides an early definition of system effectiveness. It describes the "systems-resource centered" and the "goal-centered" views of effectiveness. In the systems-resource approach, system effectiveness is determined by the "attainment of a normative state" or certain accepted standards. In the goal-centered approach, system effectiveness is assessed by first determining the task objectives of the system. Then criterion measures are developed to assess how well the objectives are being achieved. "Effectiveness is determined by comparing performance to objectives."

The study describes efficiency and effectiveness objectives and the general means to measure the accomplishment of the objectives. An example of a manufacturing, MRP system is used to describe the process. Though examples of objectives and performance measures are provided, the study article is more focused on the evaluation process than overall system effectiveness issues.

Chapter 3
Research Methodology

Previous studies conducted by Anderson *et al.* (1981) and Sum & Yang (1992) indicate that the necessity for MRP-type software is well understood by production and inventory control practitioners. As materials requirements planning software (MRP I) became widely used, APICS[1] sponsored an extensive survey of their members in several regions of the United States to study Materials Requirements Planning Systems (Anderson *et al.*, 1981). This study was adapted and updated by Sum & Yang, in a study sponsored by the National University of Singapore to survey the use of MRP II systems in Singapore, 1991 (Sum & Yang, 1992). These studies provide demographic data describing characteristics of the type of companies that used MRP systems and how the MRP systems were being used. MRP computer systems have changed dramatically over the last 15 years, but no similar study has been conducted in recent years to follow up the previous work. DeLone (1988) tested documented factors as independent determinants of success. The DeLone, Anderson *et al.*, and Sum &Yang studies were primary references in the development of the survey for this study.

3.1. The Survey Participants

This study was designed to use a mail survey to gather data about the use of manufacturing computer systems. A mail survey provides the most appropriate method to obtain relevant, up-to-date information from a large sample of companies across industries. The survey was targeted for individuals involved with the management of manufacturing computer systems. Possible titles of survey respondents were MIS Manager, Production and Inventory Control Manager, Materials Manager, Master Scheduler, or Production Manager.

The survey participants were selected from the membership roster of APICS. The Director of the Education and Research Foundation of APICS approved the use of the membership list for this study. Targeted survey participants were selected from a random sampling of the database of Virginia and Tennessee APICS members with the above job titles who worked in manufacturing environments. The target participant list was supplemented by membership lists of local APICS and Institute of Industrial Engineers (IIE) chapters in central and western Virginia, and eastern Tennessee. While some of the organizations surveyed are private companies with only 100 employees, many of the participants work in well known, commonly recognized corporations. In order to obtain demographic information about organizations using MRP-type systems, only one questionnaire was sent to each company.

[1] APICS: originally the American Production and Inventory Control Society, now known as "APICS, The Educational Society for Resource Management."

3.2. Survey Focus

Based on the results of previous studies and personal interviews with potential participants, the research was targeted to middle-size companies with approximately 300-1000 employees. The survey did not exclude larger organizations. However, there is evidence that smaller companies may not have the need or the financial resources to support MRP systems and that larger companies are more likely to have their own software development staff that may independently develop specialized corporate manufacturing computer systems (DeLone, 1988; Anderson *et al.*, 1981; and Sum-Yang, 1992). In order to conduct the study on a reasonably manageable scale, the population sample was targeted at approximately 250 participants and, in actuality, 245 individuals who work in organizations that potentially have MRP-type systems were sent the survey packet.

3.3. Survey Development

The results of the Sum &Yang (1992) study and the Anderson *et al.* (1981) study were used as a guide in developing the first draft of the survey instrument. A copy of the original 1981 (Anderson, *et al*) APICS survey was received from Dr. Roger Schroeder, University of Minnesota. Questions from the 1981 survey were selected and added to this survey with specific attention to include only relevant, up-to-date information. After developing the hypotheses for this study, some of which were adapted from the DeLone (1988) study, other questions were added to collect data on specific organizational characteristics. In Part III of the survey, survey participants are asked to rate the performance of various aspects of their MRP-type computer system. Most of these questions pertaining to computer systems performance were adapted from an unpublished survey for evaluating accounting information systems, developed by Richard B. Dull, a PhD candidate at Virginia Tech's Pamplin College of Business.

Ten people reviewed the 8-page questionnaire in detail and numerous changes were made to the wording of the questions, the format of the questionnaire and the questions, the alignment and placement of the text, and the sequential order of the individual questions. Of the 10 individuals who reviewed the preliminary survey questionnaire, 3 were professors, 3 were qualified survey participants, (i.e. individuals who worked with MRP-type systems as part of their professional jobs), 3 were graduate students, and 1 was a computer consultant with over 20 years of experience in computer systems implementation and MRP applications.

The final version of the survey is an eight page questionnaire that takes approximately 40 minutes to complete. The questionnaire is divided into 3 parts:

Part I consists of 25 mostly multiple choice questions that describe the characteristics of the organization and the type of computer system that it uses,

Part II consists of 5 sections that further address the characteristics of the MRP computer system and how it is used by the organization.

Part III consists of 2 sections in which the survey participant is asked to rate the accuracy of the data in his or her MRP system and the various aspects of the MRP computer system performance.

A copy of the survey can be found in **Appendix C.**

3.3.1. Testing the Survey

While developing the survey, three on-site interviews were conducted with qualified survey participants, each at a manufacturing plant in southwest Virginia that has MRP or ERP computer systems. Each of these three professionals reviewed the survey questionnaire in detail, provided comments, and asked questions about issues that needed to be clarified. The descriptions these three people provided about their computer systems are documented below.

To maintain anonymity, actual names have not been used for the people interviewed, neither have actual names been used for the companies described below. "Company A" has a MRP system that was installed several years ago. However, the company is not currently using the system and could not complete the entire survey. The survey was completed in full by "Company B" and "Company C." No significant modifications were made to the questionnaire after their answers were provided. The answers they provided are included in the summarized survey responses data (Appendix F), Company B is listed as survey participant number 0.1 and Company C as number 0.2.

3.3.2. Three Cases of MRP Implementation and Usage

The following cases are examples of three different companies and their usage and implementation of MRP-type systems. It should be noted that while these companies may have similar reasons for using a MRP system, there is a broad range in the hardware and software tools they are using. The method by which the companies are implementing their computer systems vary tremendously, and the capabilities of the systems are also quite different.

"Company A"

This site for Company A produces electronic products and components as well as electrical machinery. Approximately 550 people work at this site which also serves as the headquarters of the corporation. The company has four other plants along the east coast. Currently, each of the plants have different manufacturing computer systems.

There are approximately 4000 end items in the company's database. A MRP computer package that runs on an IBM AS400 was installed at the plant in 1988. There has been some, though not extensive, software modifications made to this system over the years. The MIS manager who was interviewed noted that this MRP system had not been used for some time. The data in the computer system was not accurate nor reliable and the system was not effective and eventually not used.

Spreadsheets were the only computer applications being used to schedule and support production processes. The MIS manager noted that the organization currently had a serious problem failing to meet on-time delivery dates. He emphasized that the computer system is a tool and only as good as the data that are entered into it. The usefulness of the computer system is dependent on the attitude of top management in requiring the system be used and that data within the computer system are kept up-to-date.

The top management of Company A had, within the past year, committed to the installation of a new, client-server, "enterprise resource planning" system. The vendor Company A has selected is the fifth largest in today's MRP market. A company located nearby that competes with Company A for some business contracts had selected the same software vendor. Company A has hired a consulting firm to set up this new ERP system, to write the conversion program, to train key users, and handle implementation issues.

A major factor in the company's decision to invest in a new ERP system is due to the "Year 2000" or "Millennium" problem. The accounting package Company A is currently using cannot handle the four digit year. (This is a common problem that many companies have found with computer software applications written more than 10 years ago. Many software programs only allowed 2 digit storage allocation for the year, e.g. "96" rather than "1996" and will require serious overhaul or replacement within the next 3 years.) Company A intends to have the first stage of this ERP system installed by the end of 1997. All of the company's plants are scheduled to be converted to this standard system.

"Company B"

Company B is a corporation with several different plants that are actually part of two different organizations that had merged. The organization is in the electronic products and components industry, producing fabricated metal products and electrical machinery and apparatus. The company hired a new chief information officer approximately one year ago to spearhead the effort to update, implement, and standardize the corporation's computer system.

There are nearly 850 employees in the overall corporation, approximately 400 of whom work at one primary facility. Annual sales revenue for the corporation are over $200 million while the sales revenue for the division is in the $51 - $100 million range. The facility is using 3 different computer applications for supporting manufacturing production. In 1984, the company first installed the MAPICS MRP package that runs on an IBM AS400

minicomputer. The software was vendor supplied and software modifications were done internally. There are thousands of end items and component parts produced at this facility. The bill of materials module has an average of 4 levels and the master production schedule (MPS) is updated weekly.

The accuracy of the data in this MRP system is rated below 90% with the data in the master production schedule and capacity plan sections rated less than 80% accurate, or "poor." Interviewed MRP users generally agreed that for an MRP system to be useful, the data in the computer system need to be 95% accurate or higher. Data that is 90% accurate has limited applicability for day-to-day operations.

Within the last year the new CIO, who has experience with MRP & ERP systems implementation, organized a group of 45 people across different functions within the organization to determine the required specifications for a new computer system for enterprise resource planning. A cross-functional team was formed as the steering committee and a complete package was prepared, fully documenting specific company requirements for the new computer system. Given the specified system requirements package, 10 advanced MRP software providers were invited to bid on the installation of the software. (The CIO indicated that the company never seriously considered an SAP system because the implementation cost of SAP is 6 times higher than that of other software systems.) Of the 10 software providers 4 declined, stating that they were unable to meet all the requirements. A software provider and a consulting company were selected to implement the system. The new ERP system is currently being installed and will go on-line in 1997. Company B estimates that $2.5 million has been invested in hardware and software for this new ERP system.

"Company C"

Company C is a plant that produces lighting equipment, electrical apparatus and supplies made with formed metals. The plant is part of a larger corporation, however it functions somewhat independently of the parent company. There are between 300 and 600 employees working at Company C. This organizational group within the parent company has annual sales revenues in the $100 - $200 million range.

The company is satisfied with the existing MAPICS MRP system that was installed in 1981 on an AS400 minicomputer. Company C employs software programmers who are available to make software modifications as needed. In terms of reliability, convenience, effectiveness, customer satisfaction, and usefulness, the performance of the MRP system was given the highest possible rating. The accuracy of the data in the system was generally in the 91-95 % range or higher; this is considered very good data accuracy.

The plant has approximately 2000 end items and 1500 component parts in its database. Typically there is only one level in the bill of materials (BOM) module; on occasion, some

products will have two levels. The master production schedule (MPS) is updated daily while the system is updated weekly using regenerative replanning cycles.

The employees at this facility are satisfied with the performance of their current MRP system. The company employs several schedulers and a full programming staff. The labor requirement for maintaining this batch processed MRP system may be considered higher than that of other systems. The master schedule supervisor of Company C, who provided this information, indicated that the parent company intends to adopt SAP software. However, given the high performance of the current system, the employees at this plant have been highly resistant to completely changing from the current the MRP system to SAP.

3.4. Implementing the Survey

The actual mechanics of implementing the survey primarily involved compiling a list of potential survey recipients and manually preparing the survey packets for the mass mailing.

3.4.1. Obtaining a List of Potential Participants

In developing a list of potential survey participants, local Institute of Industrial Engineers (IIE) and APICS members provided regional contacts from whom lists of local chapter presidents were obtained. Several local chapter presidents of both organizations were telephoned and it soon became apparent that while few IIE members worked closely with MRP systems, a large percentage of APICS members were involved with MRP-type computer systems in their professional careers. APICS, however, is an organization whose membership lists are very frequently targeted for mass mailings by commercial groups and other professional organizations.

The local board of the Central Virginia Chapter of APICS approved the use of its membership list for this study. However, executive members of the Tri-Cities APICS Chapter suggested that I contact the national Education and Research Foundation of APICS. A formal letter explaining the study was sent to the director of APICS' Education & Research foundation. APICS was quite willing to provide the mailing addresses for the survey.

In selecting the APICS members to target for the study, the technician working with the APICS database was asked to search for members who worked in manufacturing environments with job titles in production or inventory control management, MIS management, scheduling, or materials management, and not to select potential participants by industry type.

3.4.2. Preparing the Survey Packets

Once the mailing list was compiled, a prototype survey mailing packet was was prepared. The survey packet included six items: (1) a cover letter introducing the survey, printed on Virginia Tech, ISE Dept. letterhead [Appendix E], (2) the stapled, 8 page "Survey of Computer Systems Usage in Manufacturing" [Appendix C], (3) an informed consent form, as specified for research at the university involving human subjects [Appendix B], (4) a 2.5 by 4 inch "Summary Request Card" printed on green cardstock, (5) a self-addressed stamped envelope for returning the survey, all of which were stuffed in (6) a large, brown kraft envelope.

A total of 245 survey packets were mailed. There were 110 surveys mailed to companies in Virginia, and 135 mailed to companies in Tennessee. Five completed surveys were received in the mail just one week after the first survey packets were mailed out. Survey responses were received steadily over the course of a month, until just after the deadline specified in the informed consent form, four weeks after the initial mailing.

Chapter 4
Results and Discussion

4.1. Summarized Survey Results

The survey packets were mailed directly to APICS members in Virginia and Tennessee who were noted as potential MRP/ERP users. The recipients did not have advanced notice about receiving the survey packets, nor did they receive any reminders about participating in the study or returning the questionnaires. No financial incentives or rewards were offered for participation. Ninety-three completed survey responses were received of the 245 surveys distributed (37.96%), an excellent response rate for a one-pass mail survey (Fowler, 1988, p. 67).

This response rate indicates that there exist a significant population of manufacturing organizations that must face the challenge of integrating distributed computer systems to support production processes. Several respondents noted that their organizations did not currently use a MRP-type system, but they were interested in the results of the study simply because the companies are in the process of evaluating MRP/ERP systems.

Of the 93 survey responses received, 17 were from companies that are not currently using MRP/ERP systems. Of these, some were from industries in which MRP may not be applicable (US Postal Service, Government Consulting distribution center, boat maker, printing, etc.). Five of these companies produce fabricated metal products, and 2 specifically noted that they have begun investigating MRP-type systems for their organizations. Three of the participants noted they are not currently using a MRP-type system but are in the process of installing and implementing a MRP/ERP system.

It may be worth noting that in the Anderson *et al.* (1982) survey of APICS members in the U.S., questionnaires were sent to 1700 firms of which 679 or 40% responded, 433 of which (or 64%) of those responding indicated that they had MRP systems in place or in some stage of development. The 1981 survey targeted the upper midwest states (Region III and IV of APICS) between North and South Dakota, and New York, Pennsylvania, and West Virginia.

This was a much smaller study with a sample population of 245 firms of which 93 or 38 % responded, 76 of which (82 %) indicated they had some sort of MRP system in place or in development. The percentage of those responding in 1996 that use MRP-type systems was much higher (82%) than the 1981 results (64%). These data indicate that a larger percentage of companies in manufacturing may have adopted MRP-type systems over the last 15 years.

4.2. Company Profiles of MRP Users

A wide variety of industries were represented in the survey responses. Table 1 shows the industry type of the MRP users responding to the survey. Several of the companies were classified in more than one industry type; this was especially true for companies that produced automotive and electronic components, electronic machinery, and fabricated metal products. As noted in previous studies, the largest representation of MRP companies were from the automotive and electronic products and components, fabricated metal products, electrical machinery, and machinery and transport equipment industries. According to Sum and Yang (1993, p. 189), "In these industries, materials management and scheduling are the (primary) operational concerns and it is no surprise that MRP is more readily found in these industries."

It should be noted that the MRP users in this 1996 study were not nearly as concentrated in the above mentioned industries as they were in the Anderson *et al.* and Sum-Yang studies. Compared to the previous studies, this study had a higher percentage of MRP users in the pharmaceutical and chemical industries, and a significantly higher percentage of MRP users in the plastics and textiles industry. The additional MRP systems users in these industries suggests that computer systems for material resource planning are growing in popularity in less traditional manufacturing industries. Industries experts claim "MRP II began erupting from traditional manufacturing into other areas. Service companies, hospitals and chemical processors enjoy its benefits..." (Thomas, 1997).

Table 1. **MRP Users Industry Type**

Industry Type	No. of Companies	% of Survey Group
Automotive Components	5	6.7
Electronic Components	13	17.3
Electrical Machinery	9	12.0
Fabricated Metal Products	17	22.7
Machinery & Transport Equipment	11	14.7
Paper	5	6.7
Pharmaceutical, Chemical products	6	8.0
Plastics	7	9.3
Textiles	5	6.7
Furniture	2	2.7
Transportation	1	1.3
Flat Glass	1	1.3
Fiber Boats	1	1.3
Food Processing	1	1.3
Instrumentation	1	1.3
Total Companies	76	

Of the 76 surveyed companies using MRP, 19 of them were independent plants while

57 were part of a larger corporation. Over half (46) of the companies surveyed indicated that they are part of a corporation with over $200 million in annual sales revenues. The median annual sales revenue of the facility or the division of the plant surveyed is between 51 to 100 million dollars, while 6 companies noted annual sales revenues of less then $20 million, 16 companies noted annual sales revenues of over $200 million for their facility or division (See *Figure 2*).

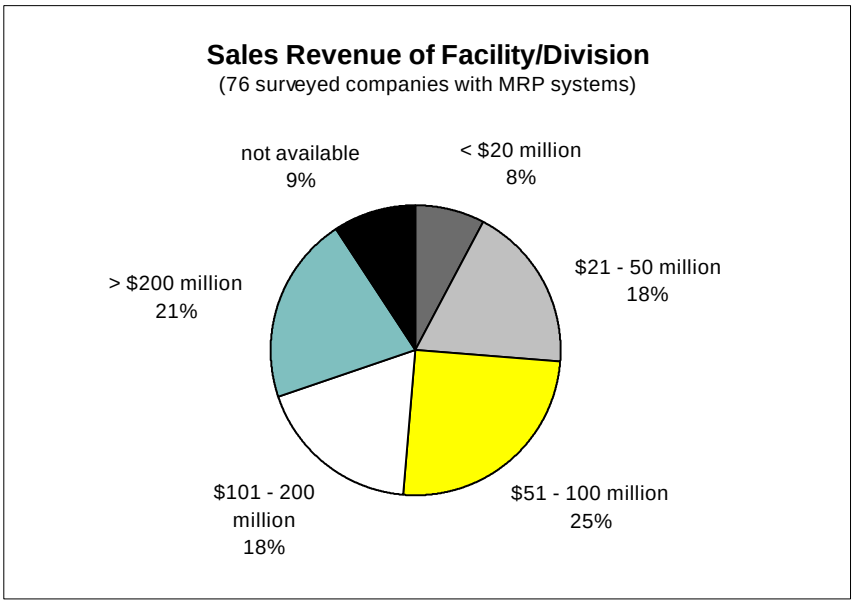


Figure 2. **Sales Revenue of Facility/ Division**

Of the companies using MRP, twenty-three employ between 101 to 300 people, twenty-one companies employ between 301 to 600 people, twelve companies have between 601 and 1000 employees, while nineteen companies note that there are over 1001 employees on site (See *Figure 3*).

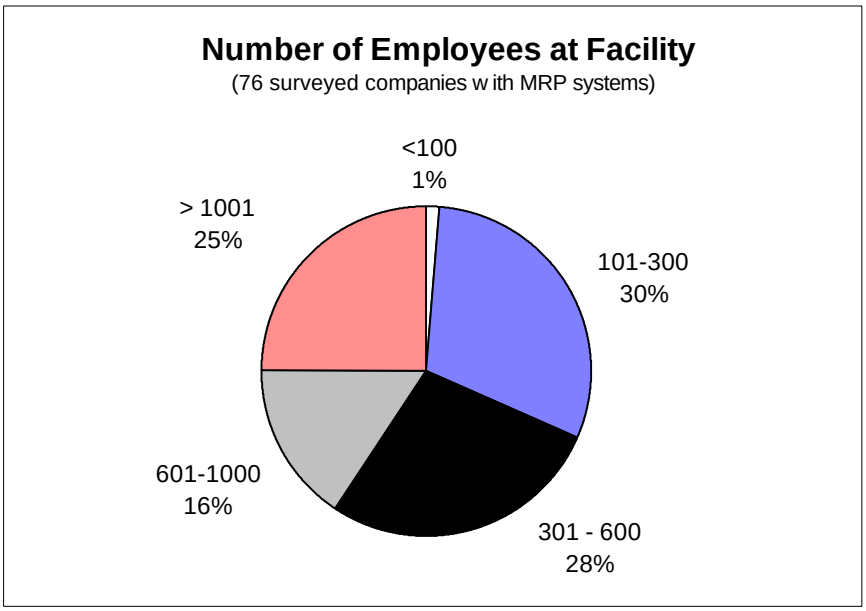


Figure 3. **Number of Employees at Facility**

Of the companies that indicate they use MRP-type systems, 28 indicate that manufacturing support is provided by one computer system while 21 others indicate that two different computer systems or applications are used (*Figure 4*). While a few companies use three, four, or five different applications, there are fifteen companies in which seven or more computer applications are used for manufacturing support. Several companies note that spreadsheets are still commonly used for scheduling. It is surprising that so many companies with MRP systems still utilize as many as seven or more computer software applications for manufacturing support. The reasoning for this may be worth investigating in future studies.

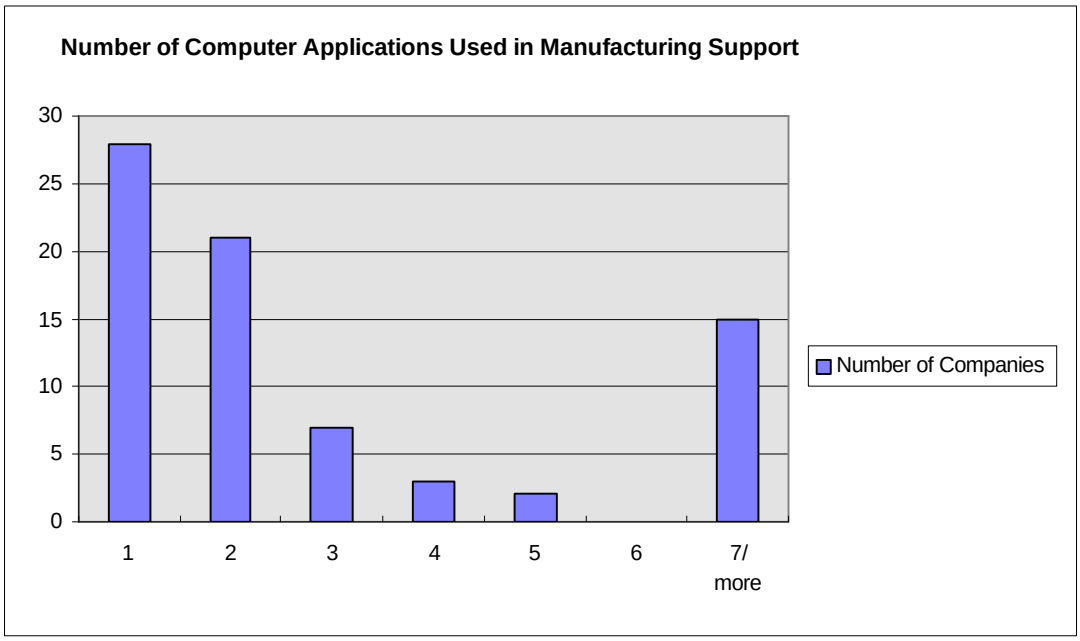


Figure 4. **Number of Computer Applications Used in Manufacturing Support**

4.3. MRP System Characteristics

Of the MRP users participating in the survey, 80% used a combination of mainframe, minicomputer, networked personal computer, and pc hardware while only 20% of the companies relied on one of the hardware types. Many organizations had two, three, or even all the hardware options. The percentage of the companies using each of the hardware types is listed in *Table 2* and *Figure 5*.

Table 2. **Hardware used for Manufacturing Computer Support**

Num. of Companies	% of MRP users	Type of Hardware
53	69.74	Mainframes
34	44.74	Minicomputers
56	73.68	Networked PC's
29	38.16	Stand-alone PC's

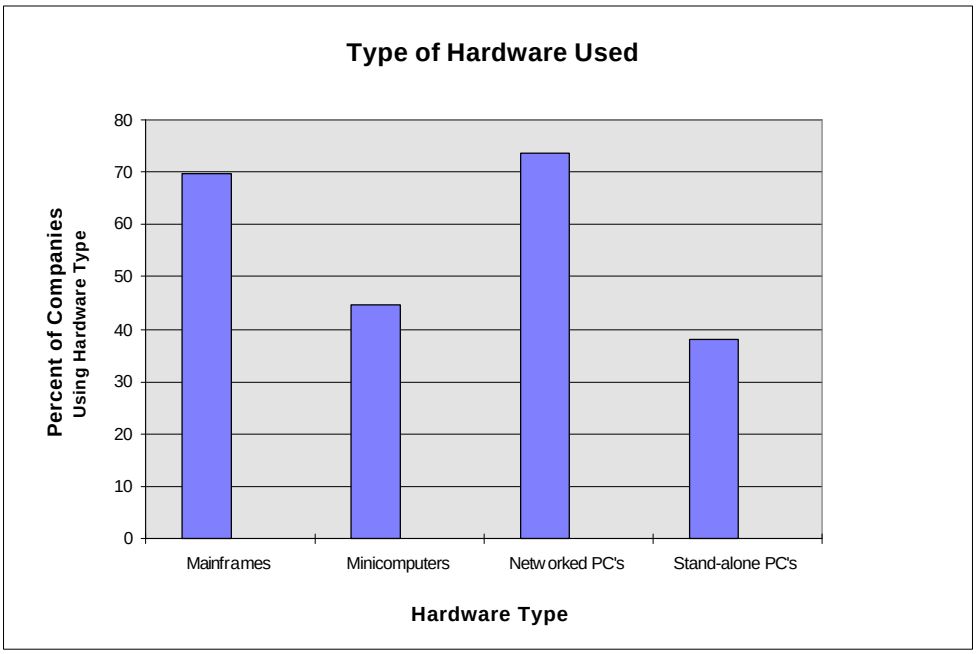


Figure 5. **Type of Hardware Used by Survey Participants Using MRP**

Twenty-six percent of the 76 companies operated their MRP systems on mainframe or minicomputers without networked personal computers. However, 74% percent of MRP users have local area networks and, 67% use a combination of local area networks with mainframe or minicomputers. The large number of companies using networked personal computers and the combination of LANs with mainframe and minicomputers implies that companies are acquiring the software required for client-server computer hardware systems which support many of today's newer enterprise resource planning (ERP) systems.

Of the survey participants using MRP-type computer systems over half have already invested more than one million dollars in the hardware, software, and external technical services for the MRP system. A quarter of the companies have invested over two million dollars in the MRP system. However, it is worth noting that smaller companies have also invested significant amounts of money in smaller systems. Twenty-two of the companies (29%) have MRP-type systems in which $500,000 or less have been invested. *Figure 6* shows the distribution of the total MRP-type system investment among survey respondents using MRP-type systems.

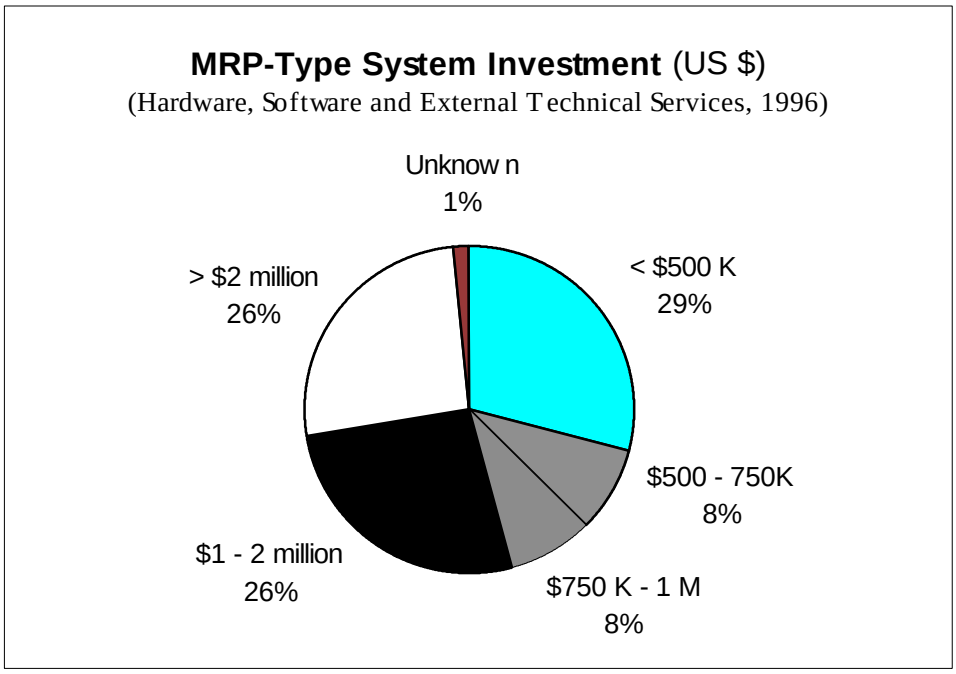


Figure 6. **MRP-Type System Investment Costs**

Figure 7 show the additional investment in MRP/ERP hardware and software that survey respondents plan for the next three years. Responses to this survey indicate that some companies have recently replaced their original mainframe based MRP system and the investment in their new MRP-type system is complete while other companies indicate that they are expecting to implement new MRP or ERP systems within the next 2 years. *Figure 7* suggests that there are two major groups for additional investments. A sizeable portion (27%) of the respondents indicate their companies plan to invest over $1 million within the next 3 years while one third of the respondents indicate additional investments of between $50,000 and $ 500,000 are planned.

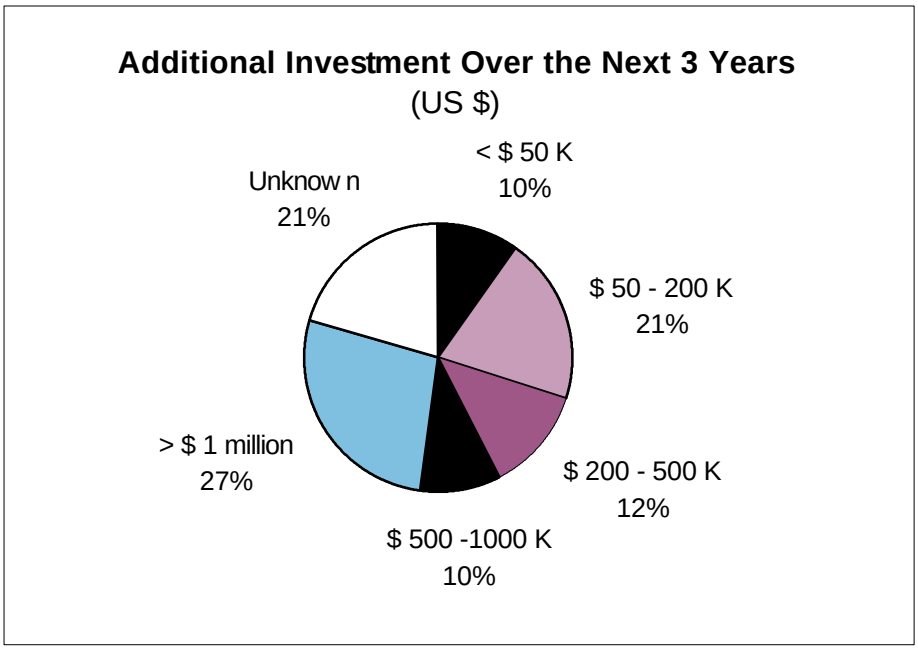


Figure 7. **Additional MRP-Type Investment Over the Next 3 Years**

Sixteen percent of the companies using MRP developed the entire software in-house while seventeen percent purchased a turn-key system that had little or no modifications. The vast majority of the software was vendor supplied with some modifications (34 %) or major modifications (33 %).

Computerization is the essence of MRP implementation. Companies will install only those modules that meet their specific requirements. The level of computerization of MRP modules reported in this survey is considerably higher than in previous studies. Across the different functions of organizations, the level to which functions have been computerized is nearly 20% higher in this study than that reported in the Sum-Yang (1992) study. *Table 3* presents the degree of computerization for various MRP modules.

Table 3. **Degree of Computerization of MRP modules**

Module	Mean Score*
Accounts payable/Accounts receivable	4.50
Inventory management/ Inventory Stock System	4.48
Bill of Materials	4.46
Sales order processing/ Order entry and invoicing	4.46
Purchasing and receiving	4.28
Materials requirement planning	4.24
Cost Accounting	4.16
Payroll/personnel	3.91
Master production schedule	3.87
Routing/work centers	3.49
Sales analysis	2.97
Product Data Management	2.96
Forecasting End Items	2.84
Shop floor control	2.83
Detailed operations scheduling	2.41
Capacity requirements planning	2.24

* Based on a six-point Likert scale, score '0' for 'not at all', '1 for '1-20%', ... , '5' for '81-100% (see Survey, Appendix C, part II B)

The average degree of integration between functions is reported to be approximately 50%.

4.4. Hypotheses Tests and Statistical Analyses

In addition to determining characteristics of organizations that use MRP systems, this study examined the performance of MRP computer systems as it relates to organizational effectiveness. Data were collected for determining relationships between the performance of the MRP computer system and characteristics of organizations in which the systems are used.

Previous MRP related surveys did not collect data specifically related to the determinants of performance. The Anderson *et al.* (1981) study focused more on the operational performance and differences between companies with MRP systems and those that did not have MRP systems. The Sum & Yang (1992) study provided more information about the problems, costs, and benefits of companies using MRP. Sum-Yang also made comparisons between MRP usage in Singapore and MRP usage in the United States.

The statistical tests and data analyses were performed using Minitab, SAS, and Microsoft Excel software. The correlation, anova, and 2-sample t-tests were conducted using Minitab version 10.5 on a pentium processor. SAS release 6.09 running on an IBM Model RS/6000 was used for the principle components analysis, and Excel 5.0 IBM-PC version was used for basic statistics.

4.5. The Performance Measures

Aside from determining the current level of computerization and MRP usage, the remaining hypotheses test for relationships between MRP systems performance and (1) upper management involvement, (2) the level to which the MRP software is customized for an organization, (3) the length of time that an organization has used MRP-type systems, (4) the level of employee training on the MRP system, and (5) the implementation of quality and productivity improvement programs such as TQM.

The quantitative performance measure is determined from the questions in Part III of the survey. The questions in Part III, section B, were designed to rate the computer system in terms of convenience, reliability, customer satisfaction, effectiveness, availability, and information relevance. The questions in section III-A ask the user to rate the accuracy of data in different functional modules of the MRP computer system. Section III-B provides a broader measure of overall systems performance while section III-A provides a less subjective measure of the "correctness" or accuracy of the data in the computer system (see *Appendix C*).

Using the first 20 completed surveys received, a preliminary statistical analysis was conducted. It became apparent that the two groups, section III-A and section III-B, could not justifiably be combined into one performance measure. While accuracy may be accepted as a part of overall systems performance, its fractional proportion and relative weight is undetermined. Furthermore, the rating scale for section III-A is based on a 7-point Likert scale while section III-B rates accuracy on a 4-point Likert scale. Therefore, the hypotheses were tested against two numeric values, one measure for overall performance and one measure for data accuracy.

The overall performance value is an estimate of the perceived performance of the organization's computer system. A better performance measure can not be justified without more research and more in-depth testing. The accuracy measure is an average of the data accuracy in each of the functional modules used in the computer system. This assumes that the different modules have the same relative importance in the overall system.

The questions used for rating performance in *section III-B* were designed to evaluate the following factors:

Survey Questions (III-B)	*Associated Performance Factors*
1,11	Perceived relevance of information
2	Convenience for obtaining information
3,7	Perceived Software Reliability
4,5,6,8,10	Perceived effectiveness of system as a tool
9	Perceived customer satisfaction
12	Overall Satisfaction

In determining the relative weights of the 12 questions and six factors for the overall performance measure, the apparent interdependencies of the factors were considered. Due to the apparent overlapping relationships between the factors, the option of weighting the factors using the Multi-Criteria Productivity/Performance Measurement Technique (Sink and Tuttle, 1989) was not applied.

Using the answers to the twelve questions in section III-B provided by the first 20 subjects, a **principle components analysis** was performed. This test indicated that the answers to the twelve questions were all highly correlated, and there is only one primary dimension in the overall analysis of the data set. The principle components analysis for the complete data set can be found in Appendix G.

The eigenvalue for the first dimension of the dataset is 8.087, ten times greater than that of the second dimension, 0.798. The first dimension also accounts for 67% of the variance. This is also ten times greater than the variance attributed to any other dimension (6.65%). Furthermore, all 12 questions exhibit eigenvectors near 0.3, between 0.262 and 0.329. The narrow range of the eigenvectors and the magnitude of the first dimension of the data set implies that an overall value for performance should be determined by simply using a straight average to sum the answers to the 12 questions rating performance.

In the preliminary test, the questions expected to measure system effectiveness, questions 4,5,6,8, and 10, were grouped together and represented as one factor to test if this would determine a different weighting scheme for the data. There was no significant difference found by using this grouping. The eigenvalues still indicate the variance for the data is attributed to one primary dimension, and there was no noticeable increase in the eigenvector for the combined system effectiveness questions. Question number 8 in section III-B appeared to be slightly less correlated than the other questions. This may have resulted from the more specific phrasing of the question. However, this slight difference did not warrant a change to the weighting of the questions. Thus, the overall performance value was also calculated as a straight average of the questions (see Appendix H).

APICS developed a 4-level classification system for ranking MRP usage (see section 3.2, p. 29). Using the data collected in the survey, the expected APICS classification for an organization generally aligned with the overall performance measure. Lower performance ratings used for this survey (2.5 or less) tend to be class C or class D organizations, while class A and class B organizations consistently received higher performance ratings in this study.

The actual hypotheses tests and statistical analysis follow in section 4.6. A summary of the results of the tests can be found in section 4.7.

4.6. The Statistical Tests for Determinants of MRP System Performance

The previous sections on company profiles of MRP users (section 4.2) and MRP systems characteristics (section 4.3) provides data for the first research hypothesis dealing with the level to which companies and production functions have been computerized. The remaining hypotheses, hypothesis numbers 2 - 6 (section 1.9, page 6) are individually tested in this section using specific questions from the survey and basic statistical tests for correlation, analysis of variance between groups, and 2 sample t-tests for significant differences. Section 4.7 provides a general discussion of the results of the hypotheses tests.

4.6.1. Upper Management Involvement

Hypothesis 2: The Performance of MRP Systems is Highly Related to Upper Management Involvement.

Upper management involvement is actually tested using the following four dimensions:
(A) the level of upper management support,
(B) upper management initiation of the computer system implementation
(C) the level of upper management involvement in implementation, and
(D) the level of upper management knowledge of computer systems.

Hypothesis 2A: The performance of MRP-type systems is directly related to the level of upper management support for the implementation and project management of the MRP computer system.

H_0: $\rho = 0$ There is no correlation between the MRP performance and upper management support.
H_1: $\rho \neq 0$ There is a correlation between MRP performance and upper management support.

Decision Rule: Reject H_0 if $t_{observed} > t_{critical}$ where $t_{critical} = t_{table}$ at $\alpha = 0.05$

The answers to Question 17, Part I of the survey was used to test this hypothesis. The data used for this test can be found in Table I.1. of the Appendices. Question 17 asked the following:

To what extent does top management support the implementation and project management of the MRP computer system?

a) Very little or Not at all
b) Limited support
c) High level of support
d) Entirely support

The answers to this question were converted to levels 1 - 4
where Category A, "Very little or not at all" became Level 1 and
Category D, "Entirely Support" became Level 4.

(Other questions where scaleable levels were used as categories, specifically Part 1, Questions 15 and 16, were similarly converted to numeric data for the purpose of statistical analysis on Minitab.)

Using this categorization for the level of upper management support, tests for correlation between the level of upper management support and the two performance measures (see section 4.5) were conducted. The overall performance rating and the level of upper management support for the implementation was tested for correlation.

A similar test was conducted to test for correlation between the level of upper management support and the performance measure for accuracy rated for each of the companies.

A correlation coefficient was calculated and the observed t-value determined using the standard formula for calculating the observed t-value:

$$t_{observed} = |r| \sqrt{(n-2) / (1-r^2)}$$ where n = number of observations and r = the calculated correlation coefficient.

Using a sample size of 76, the correlation between **overall performance** and level of upper management support is 0.362. The observed t-value is 3.341, yielding $p < 0.001$. The table value for $t_{(\alpha = 0.05,\ n-2 = 74)} = 1.666$. Thus, H_0 is rejected and it is concluded that MRP performance and upper management support are indeed correlated.

The test for correlation between data **accuracy** in the MRP system and the level of upper management provides the following results. Pearson's correlation coefficient is found to be 0.361. This t-value is calculated to be 3.330 and the p-value is also less than 0.001. Likewise, upper management support and the accuracy of the MRP system are also correlated.

The statistical tests support a strong correlation between the stated performance of the MRP-type computer system and the level of upper management support for the computer systems. There is also strong correlation between the level of upper management support for MRP computer systems and the accuracy of the data available in the system.

Hypothesis 2B:
Is the performance of MRP-type computer systemssignificantly better in companies where the implementation was initiated by upper managementas opposed to companies in which the development of the computer system was initiated by someone other than upper management?

H_0: $\mu_{init} = \mu_{not}$ There is no difference between the two groups.

H_1: $\mu_{init} > \mu_{not}$ Performance of MRP computer systems initiated by upper management is higher than performance of those initiated by others.

Decision Rule: Reject H_0 if $p < 0.05$,
i.e. $t_{observed} < t_{critical}$ where $\alpha = 0.05$

The data for this test came from Question 13**,** Part I of the survey. The data used for this test can be found in Table I.2. of the Appendices. Question 13 asked the following:

Who initiated MRP development in your company?
a) Top management
b) Production and inventory control management
c) Both top management and production and inventory control management
d) Information systems
e) Software and hardware vendors
f) Other (describe) _____

Using the answers to this question, two categories were compared. Survey respondents who answered (a or c) were placed in Category 1, those having top management initiative. All others were grouped in Category 2, initiated by someone other than top management. The overall performance of companies in which top management initiated MRP development was compared to the performance of companies in which the system was initiated by someone outside of top management.

The performance of upper management initiated systems was tested against systems not initiated by upper management using a 2-sample t-test where

μ_{init} = The average of the overall performance rating of the companies in which upper management initiated the MRP-type computer system implementation. (MGTInitP)

μ_{not} = The average of the overall performance rating of the companies in which the MRP-type computer system implementation was initiated by someone other than upper management. (NotMGTIP)

```
Twosample T for MGTInitP vs NotMGTIP
            N      Mean     StDev
MGTInitP   53      5.61      1.14
NotMGTIP   23      5.17      1.56
```

The observed t = 1.20 and p = 0.24. The test demonstrates that the two groups are not significantly different.

The averaged accuracy ratings of upper management initiated systems was also tested against the averaged accuracy ratings of systems not initiated by upper management using a 2-sample t-test where

μ_{init} = The average of the accuracy ratings of the companies in which upper management initiated the MRP-type computer system implementation. (MGTInitA)

μ_{not} = The average of the accuracy rating of the companies in which the MRP-type computer system implementation was initiated by someone other than upper management. (NotMGTIA)

```
Twosample T for MgtInitA vs NotMGTIA
            N      Mean     StDev
MGTInitA   53     2.508     0.581
NotMGTIA   23     2.421     0.843
```

The observed t = 0.45 and p = 0.66. Similarly these data support that upper management initiation also does not affect the data accuracy of MRP-type computer systems.

The 2 sample T-tests support that upper management initiation did not demonstrate a relationship with higher levels of accuracy or overall systems performance. Both calculated p-values were much larger than 0.05, and no significant difference was established between the two groups.

Hypothesis 2C:

The performance of MRP-type computer systems is significantly correlated with upper management involvement in implementation.

H_0: $\rho = 0$ There is no correlation between the MRP performance and upper management involvement.

H_1: $\rho \neq 0$ There is a correlation between MRP performance and upper management involvement.

Decision Rule: Reject H_0 if $t_{observed} > t_{critical}$ where $t_{critical} = t_{table}$ at $\alpha = 0.05$

The data for this test came from Question 15, Part I of the survey. The data used for this test can be found in Table I.3. of the Appendices. Question 15 asked the following:

To what extent is someone in upper management involved with implementing the MRP system?

a) Not at all
b) Slightly involved
c) Moderately involved
d) Highly involved

These levels of categorization were also converted to levels 1- 4, with level 4 representing the most highly involved upper management. Using this categorization for the level of upper management involvement, tests for correlation between the level of upper management involvement and the measures for overall performance and accuracy (see section 4.5) were again conducted.

Using the performance rating for each of the companies, the overall performance of MRP systems increased with the level of upper management involvement. The test for correlation between upper management involvement and performance yielded a correlation coefficient of 0.152, t =1.323 and p = 0.095, indicating that upper management involvement is not significantly related to the performance of the MRP computer system at $\alpha = 0.05$.

The same test performed using the accuracy ratings yielded a correlation of 0.195 between accuracy and upper management involvement, t = 1.71 and p = 0.046, indicating that at $\alpha = 0.05$, upper management involvement is correlated with the accuracy of the computer system.

The data indicate that upper management involvement is correlated to the accuracy of the computer system. However, the overall performance rating of the computer system is not significantly correlated with management involvement in implementation

---

Hypothesis 2D:
The performance of MRP-type computer systems is significantly correlated with upper management knowledge of computer systems

H_0: $\rho = 0$ There is no correlation between upper management knowledge of computer systems with MRP performance.

H_1: $\rho \neq 0$ Upper management knowledge of computer systems is related to MRP performance.

Decision Rule: Reject H_0 if $t_{observed} > t_{critical}$ where $t_{critical} = t_{table}$ at $\alpha = 0.05$

The data for this test came from Question 16, Part I of the survey. The data used for this test can be found in Table I.4. of the Appendices. Question 16 asked the following:

To what extent is a high-level manager knowledgeable of computer systems.

a) Not at all
b) Slightly knowledgeable
c) Moderately knowledgeable
d) Highly knowledgeable

The answers to this question were converted to levels 1 - 4
where Category A, "Not at all" became Level 1 and
Category B, "Highly Knowledgeable" became Level 4.

Using the performance rating for each of the companies, the organizations were categorized by level of upper management knowledge of computer systems. Correlation tests were conducted to determine if the general performance of MRP systems increased with upper management's knowledge of computer systems.

The test for correlation between performance and upper management knowledge yields a correlation coefficient $r = 0.281$, $t = 2.51874$ and $p = 0.007$.

The test for correlation between accuracy and upper management knowledge yields a $r = 0.245$, $t = 2.174$ and $p = 0.0165$.

The correlation tests indicate that the level of upper management knowledge of computer systems is highly correlated to both the accuracy and the performance of the computer systems.

4.6.2. The Level of MRP Software Customization

Hypothesis 3: The performance of a MRP computer system is related to the level to which MRP software is specifically developed and customized for the organization.
-or-

The amount of the software that is vendor supplied without modification is related to the performance of the system.

H_0: $\rho = 0$ There is no correlation between MRP computer systems performance and the level of software customization.

H_1: $\rho \neq 0$ The level of software customization is related to MRP computer systems performance.

Decision Rule: Reject H_0 if $t_{observed} > t_{critical}$ where $t_{critical} = t_{table}$ at $\alpha = 0.05$

The data for this test came from Question 10, Part I of the survey and can be found in Table I.5. of the Appendices. Question 10 asked the following:

What was the source of your MRP system?	Category of Software provided by vendor
a) Developed internally within your organization	1
b) Vendor supplied with little or no modifications	4
c) Vendor supplied with some modifications	3
d) Vendor supplied with major modifications	2

The answers to this question were translated to levels 1 - 4 and numbered by the amount of the MRP software provided by the vendor. Thus, answer "a," where the MRP software was not supplied by a vendor became category 1, answer "d," where the original software was provided by a vendor but significantly modified became category 2, and answer "b," where the vendor software was modified very little or not modified, became category 4.

The level of software customization tested against MRP system performance yields r = -0.274. The negative correlation indicates that the levels of customization were numbered in reverse order. Category 1 is the highest level of software customization while category 4 indicates the lowest level of customization. The calculated value for t = 2.451 and p = 0.008.

The means and standard deviation for the four levels are charted below.

```
Individual 95% CIs For Mean
                                    Based on Pooled StDev
 Level      N      Mean     StDev  ---------+---------+---------+-------
     1     11     5.947     1.047              (----------*---------)
     2     25     5.800     1.267                (------*------)
     3     26     5.338     1.127         (------*------)
     4     13     4.949     1.459  (---------*--------)
                                    ---------+---------+---------+-------
Pooled StDev =    1.226                  4.90      5.60      6.30
```

The level of software customization tested against MRP data accuracy yields r = -0.345, t = 3.16, and p = 0.001. The group means are charted below.

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
 Level      N      Mean     StDev  -------+---------+---------+---------
     1     11    2.8045    0.3796                (------*-------)
     2     25    2.6066    0.6453              (----*----)
     3     26    2.4987    0.6586            (----*----)
     4     13    2.0095    0.6668  (------*------)
                                    -------+---------+---------+---------
Pooled StDev =   0.6237               2.00      2.50      3.00
```

These tests show that there is strong correlation between the level of software customization specific to an organization and the eventual performance and accuracy of the MRP computer system. The average accuracy rating for companies in which vendor supplied software is used without modification is significantly lower than the accuracy of systems that were modified or developed for a specific organization. Testing software customization levels against performance also indicates a strong correlation.

4.6.3. Length of Time MRP System Used

Hypothesis 4: The length of time that an organization has used MRP-type systems is related to the performance the system.

H_0: $\rho = 0$ There is no correlation between MRP performance and the length of time an organization has used MRP-type systems.

H_1: $\rho \neq 0$ The amount of time a company has used MRP-type systems is correlated to MRP computer systems performance.

Decision Rule: Reject H_0 if $t_{obs} > t_{critical}$ where $t_{critical} = t_{table}$ at $\alpha = 0.05$

The data for this test came from Question 11, Part I of the survey and can be found in Table I.6. of the Appendices. Question 11 asked the following:

In what year did your company first install a MRP system? _____

The number of years a company has used MRP-type systems was calculated by subtracting the initial year of MRP usage (question 11) from the present year, 1997. Sixty-nine samples were used. Seven of the survey participants using MRP-type systems were uncertain of the actual year of installation at his/her company and, thus, their data were not used for this test.

The calculated Pearson correlation coefficients are listed below:

```
          Accuracy    Performance
NumYears  0.236       0.092         using 69 samples
```

Using the 0.092 value and a sample size of 69 to test for correlation between time and performance level, t = 0.756 and p = 0.226, indicating that the length of time a company has used MRP-type systems is **not** correlated with the performance of the computer system.

Using the 0.236 value to test for correlation between time and accuracy level, t = 1.99 and p = 0.025. This supports that length of time is correlated with data accuracy.

4.6.4. Employee Training on MRP Systems

Hypothesis 5: The performance of MRP-type computer systems is related to higher levels of computer **training for employees**.

Hypothesis 5A: **The performance of the system is significantly better when training is provided by one of the four groups: external consultants, internal experts, both external consultants and internal experts, or no formal training.**

H_0: There is no difference between the 4 categories of training

H_1: One or more of the training categories yield significantly different performance levels.

The data for this test came from Question 22, Part I of the survey and can be found in Table I.7. of the Appendices. Question 22 asked the following:

Training is conducted by
(1) A - external consultants
(2) B - in house experts, employees
(3) A&B - both external consultants & in house experts
(4) C - No Training

An analysis of variance test was used because these categories and do not follow a linear trend, nor is there an order of magnitude indicated in the categorization. The Minitab analysis of variance tests follow:

```
One-Way Analysis of Variance

Analysis of Variance on Accuracy
Source     DF        SS        MS        F        p
Type        3     1.210     0.403     0.90    0.447
Error      71    31.945     0.450
Total      74    33.155

                                  Individual 95% CIs For Mean
                                  Based on Pooled StDev
 Level      N      Mean     StDev  ---------+---------+---------+-------
     1      9    2.6472    0.6523               (----------*----------)
     2     33    2.4958    0.6935                 (----*-----)
     3      8    2.1428    0.6447   (-----------*----------)
     4     25    2.5210    0.6533                (------*------)
                                  ---------+---------+---------+-------
Pooled StDev =   0.6708                 2.00      2.40      2.80
```

The analysis of variance comparing performance to training type follows:

Analysis of Variance on Performance

Source	DF	SS	MS	F	p
Type	3	0.38	0.13	0.07	**0.975**
Error	71	122.68	1.73		
Total	74	123.05			

Level	N	Mean	StDev	Individual 95% CIs For Mean Based on Pooled StDev
1	9	5.408	1.285	(----------*----------)
2	33	5.518	1.298	(-------*-------)
3	8	5.646	1.363	(----------*----------)
4	25	5.428	1.331	(-------*--------)
Pooled StDev =		1.314		4.80 5.40 6.00 6.60

These ANOVA tests indicate that the accuracy and performance measures for companies that do not have formal training programs are no worse than that of companies in which training is conducted by external consultants or in-house experts. The results also indicate that training conducted by a collaborative effort between external consultants and in-house experts produced slightly better performance ratings while the accuracy level is lower than that of other groups. There was no obvious indication that training conducted by external consultants or in-house experts resulted in higher MRP performance or accuracy.

Hypothesis 5B: **The performance of the system is significantly better when the company has a budget for employee/user training**

H_0: $\mu_1 = \mu_2$ There is no difference between the two groups.

H_1: $\mu_1 > \mu_2$ The two groups are significantly different.

Decision Rule: Reject H_0 if $p < 0.05$.

The data for this test came from Question 23, Part I of the survey and can be found in Table I.8. of the Appendices. Question 23 asks the following:

Does your company have funds dedicated to training employees on the use of MRP-type computer systems, post installation?

a) Yes
b) No

A difference of means test was conducted to determine if the performance of the two groups were significantly different. The 2-sample t-test produced the following confidence intervals and test results:

```
Twosample T for AccyYes vs AccyNo

           N      Mean     StDev
AccryYes  33     2.545     0.642
AccryNo   42     2.461     0.665
```

t = 0.55 and p = 0.58

The same test conducted using the accuracy ratings yielded the following:

```
Twosample T for PerfNo vs PerfYes

          N      Mean     StDev
PerfNo   42      5.48      1.33
PerfYes  33      5.45      1.26
```

t = 0.08 and p = 0.93

In both cases, H_0 is not rejected. There is no difference in MRP computer system performance or accuracy between the companies that have funds dedicated for employee training and companies that have no budget for employee training. <u>There is no evidence to support that companies with budgets for employee training have better performing or more accurate MRP systems than companies that have no budget for MRP training</u>.

Hypothesis 5C: **The performance of the system is lower when a<u>company considers training to be a significant implementation problem</u>**

H_0: $\rho = 0$ There is no correlation between MRP performance and the level at which a company perceives training to be a problem.

H_1: $\rho \neq 0$ The level at which a company considers training to be a problem is related to the performance of MRP systems.

Decision Rule: Reject H_0 if $t_{obs} > t_{critical}$ where $t_{critical} = t_{table}$ at $\alpha = 0.05$

The data for this test can be found in Table I.9. of the Appendices. This data came from Question 6 in Part II-E of the survey, which asked the following:

From the experience your organization has had with MRP systems, rate the following *implementation problems* using the following scale:

0 = No Affect, Not Applicable (N/A)
1 = Small Problem
2 =
3 = Moderate Problem
4 =
5 = Large Problem

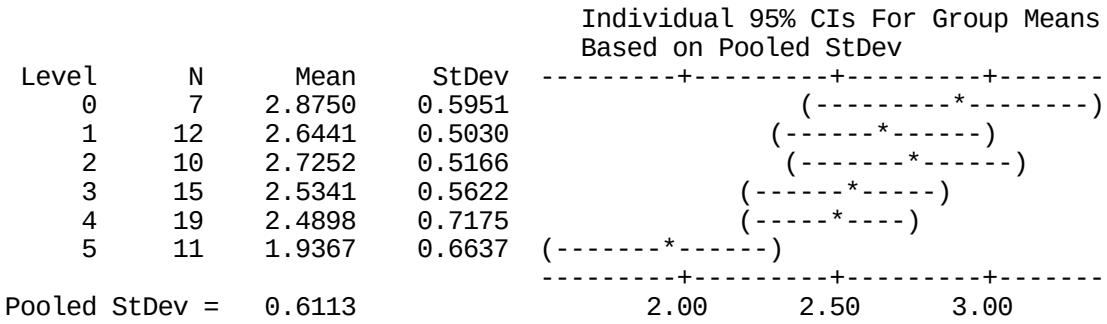
	N/A	**Small**		**Moderate**		**Large**
6. Lack of training/education on MRP	0	1	2	3	4	5

The following correlation coefficients test “level to which training is perceived as an implementation problem” against levels of MRP system accuracy and performance.

Correlations (Pearson)	Accuracy	Performance
Training perceived as problem	-0.349	-0.344

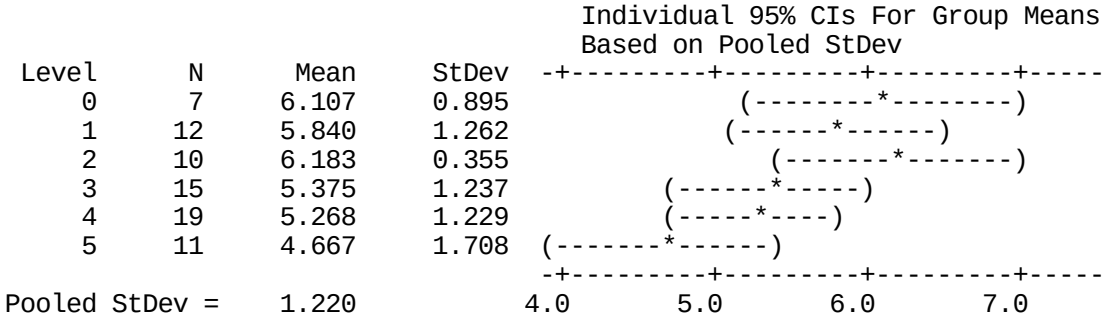
Both of these correlations are negative. The test for accuracy and “level to which training is perceived as an implementation problem” yields t = 3.160 and p = 0.001. This indicates a strong correlation between accuracy of MRP systems and the level to which training is considered an issue.

A plot of individual means from the levels to which training/education is considered a problem indicates a linear relationship between perceived level of importance for training and the accuracy of MRP systems.



Using the -0.344 correlation coefficient, the correlation test for performance against “level to which training is perceived as an implementation problem” yields t = 3.11 and p= 0.001. This indicates a strong correlation between performance of MRP systems and the level to which training is considered an issue.

A plot of individual means from the levels to which training/education is considered a problem also indicates a strong linear relationship between perceived level of importance for training and the performance of MRP systems.



The tests indicate there is a strong negative correlation between "the level to which training is considered an implementation problem" and both the performance and the accuracy of MRP computer systems. Meaning, when a company considers lack of training to be an implementation problem, the performance of the MRP computer system is likely to be poor.

4.6.5. Quality and Performance Improvement Programs.

Hypothesis 6A: Companies that have a Quality and Performance Improvement program like TQM have better performing MRP/ERP systems than companies that do not have such a program.

H_0: $\mu_{TQM} = \mu_{NoTQM}$ There is no difference between the two groups.

H_1: $\mu_{TQM} > \mu_{NoTQM}$ The two groups are significantly different.

Decision Rule: Reject H_0 if $p < 0.05$.

The data analyzed for this test came from survey answers to questions 12, 24, and 25 in Part I of the survey and can be found in Table I.10. of the Appendices.

12. In what year was your current MRP system installed? _____

24. Does your company have a Quality or Productivity Improvement Program such as TQM?
    a) Yes
    b) No
    c) It was attempted

25. If your company does have a Quality or Productivity Improvement Program, in what year was it or is it being implemented?
    a) _____ (year)
    b) No such program exists

Using the answers to Question 24, the overall MRP systems performance of companies that have quality and productivity improvement programs were tested against companies that have no TQM-type program.

The 2-sample t-test yields the following confidence level and test values for accuracy:

```
Twosample T for TQM-A vs NoTQMA
          N      Mean     StDev
TQM-A    57     2.499     0.653
NoTQMA   18     2.407     0.737
```

t = 0.48 and p = 0.64

The same test conducted for the performance data of TQM versus No-TQM groups yields the following results:

```
Twosample T for TQM-B vs NoTQMB
         N      Mean     StDev
TQM-B   57      5.55      1.23
NoTQMB  18      5.21      1.47
```

t = 0.89 and p = 0.38

Neither test demonstrates that companies with quality and productivity improvement programs have MRP systems with higher performance or accuracy. There was no significant difference in the performance and/or accuracy of companies with quality and productivity improvement programs and those with no such program.

A similar test was conducted using only companies that had TQM programs prior to MRP implementation.

Hypothesis 6B: Companies that implemented TQM (or a similar quality and performance improvement program) prior to the implementation of their MRP/ERP computer system have better computer system performance.

H_0: $\mu_{TQM} = \mu_{NoTQM}$ There is no difference between the two groups.

H_1: $\mu_{TQM} > \mu_{NoTQM}$ The two groups are significantly different.

Decision Rule: Reject H_0 if $p < 0.05$.

The data used for this test can be found in Table I.11. of the Appendices. Note, of the 76 survey respondents with MRP systems, only 10 noted their company had implemented quality or productivity improvement programs prior to MRP. (Only MRP implementations completed before 1996 were included.)

A 2-sample t-test comparing the MRP performance of the two groups generated the following results.

```
Twosample T for TQM-B vs NoTQM-B
          N      Mean     StDev
TQM-B    10      5.95      1.15
NoTQM-B  18      5.21      1.47
```

t = 1.48 and p = 0.15

A similar 2-sample t-test compared the accuracy of the two groups, producing the following confidence level and results.

```
Twosample T for TQM-A vs NoTQM-A
          N      Mean     StDev
TQM-A    10     2.677     0.678
NoTQM-A  18     2.407     0.737
```

$t = 0.98$ and $p = 0.34$

The test correlating the performance of companies with TQM programs prior to MRP implementation and those without MRP programs generated a p-value of 0.15. However, neither test provided evidence that having a quality and productivity improvement program provide higher performance outcomes for MRP systems.

4.7. General Discussion

This section summarizes the results of the hypothesis tests presented in section 4.6.

The first hypothesis tested states that **"the performance of MRP Systems is highly related to upper management support."**

This hypothesis is analyzed using four different concepts. The tests indicate that a there is strong correlation between the performance of MRP-type computer systems and the level of upper management support for MRP computer systems. This outcome reaffirms DeLone's findings (DeLone, 1988). There is also a strong correlation between the level of upper management support for MRP computer systems and the accuracy of the data available in the system. Similar tests support that upper management knowledge of computer systems is also highly correlated to the performance and the accuracy of the computer systems.

Tests for correlation between upper management initiation and MRP systems performance indicated that upper management initiation is not correlated to the either performance or accuracy of the MRP-type systems. While MRP implementation programs that are initiated by upper management may receive higher levels of upper management support, there was no significant difference between the performance of MRP computer systems initiated by upper management and those that were initiated by others in the organization. Similarly, no significant differences in data accuracy were found as a result of upper management initiation.

A significant relationship did exist between upper management involvement in implementation and the accuracy of the computer system. However, management involvement with implementation is not significantly correlated to the performance of the computer systems. These results differ from that of the DeLone (1988) study. DeLone found both the level of a chief executive's computer knowledge and the chief executive's involvement with computerization to be significantly correlated with computer based

information system success. This difference may be attributed to differences in the size of the organizations studied. The manufacturing firms sampled in DeLone's study were small companies with an average of 62 employees, none with more than 300 employees. The median size of companies in this MRP survey is between 400 and 600 employees with 1/4th having over 1000 employees.

Given that the two studies surveyed different size companies, it may be said that the involvement of a chief executive in computerization is necessary in small companies. However, top management involvement with the actual implementation of MRP-type computer systems is not necessarily significant for larger companies. In this study and in DeLone's study, upper management knowledge of computer systems is shown to be significantly correlated to the performance (or success) of computer systems.

The results of this study support that in larger companies (more than 300 people), top management does not need to be involved in the actual implementation of the computer system. Yet, someone in top management needs to be knowledgeable of these computer systems. Because of this it may be asked, "Where is this knowledge applied if the upper managers are not involved in implementation?" While upper managers in larger companies may not need to be involved in the day-to-day work of implementing a computer system, many documented cases point to the need of upper management knowledge for successful implementation. The better top managers understand the needs of their organizations and the capabilities of the computer systems they are using, the better the managers will be able to support the implementation effort.

It is also interesting to note that upper management involvement with implementation appears to correlate with the accuracy of the data in the computer system but not the overall performance of the MRP system. This could be explained by noting that accuracy is a much easier concept to evaluate and quantify. Overall performance is a more complex idea that would be more difficult to measure and evaluate. Even with higher levels of upper management involvement, managers are likely to find accuracy easier to improve than overall performance, especially if accepted measures of performance have not been defined. Hence, while numerous industry experts claim that upper management support is critical for successful MRP/ERP ventures and performance improvement efforts, the results of these tests provide empirical evidence to support such assertions.

The second hypothesis statistically tested (Hypothesis 3) states "**the performance of MRP Systems is associated with the level to which the software is configured for the organization.**"

Correlation tests indicate that the level to which the software is configured for the organization is significantly related to both the performance and accuracy levels of the MRP system. The average accuracy rating for companies in which vendor supplied software is used

without modification is significantly lower than the accuracy of systems that were modified or developed for a specific organization. Testing software configuration levels against performance produce similar results. There is strong correlation between the level of software configuration specific to an organization and the eventual accuracy and performance of the MRP computer system. This test also provide empirical evidence to support logical claims often made in industry. It should be noted that many new, recently developed MRP-type software packages are easily customized for individual companies. The software packages, many of which have graphical user interfaces developed in Visual Basic or Visual C++, allow users more options that tailor the computer system to the specific needs and limitations of individual organizations.

Hypothesis 4 states that "**the length of time that an organization has used MRP-type systems is related to the performance the system."**

The test for correlation between the number of years a company has used MRP systems indicate that time is highly correlated with data accuracy but not the overall performance of the MRP system. This was an unexpected finding but it is intuitively logical. Over time, organizations are likely to focus on the accuracy of data in the computer system. However, given the complexity of mastering the many components of performance, this does not imply that the overall performance of the MRP system will be improved.

Hypothesis 5 states that "**the performance of MRP-type computer systems is related to higher levels of computer training for employees**."

The results of the hypothesis tests indicate that the level at which a company considers training to be a significant implementation problem is strongly correlated to the performance of the MRP computer system. The tests indicate there is a strong negative correlation between the level to which training is rated as an implementation problem and both the performance and the accuracy of MRP computer systems. Therefore, the results support that companies which rate training as a greater implementation problem will very likely have lower overall MRP performance.

A statistical test was conducted to determine if the performance of the system is significantly better when the company has a budget for employee/user training. The results of the analysis indicate that there is no significant difference in performance between companies that do not have a training budget and companies that do have a budget specifically for MRP training. This suggests that having a training budget may not be a good indicator of the amount of training that a company provides.

By categorizing training methodology into four different groups, the performance of the MRP system was tested to determine if there is a significant difference in performance

between the four training groups. The four training groups categorized were (1) external consultants, (2) internal experts, (3) both external consultants and internal experts, or (4) no formal training. The analysis of variance tests performed did not demonstrate significant differences between the different training methodologies. The accuracy and performance measures for companies categorized as having no formal training programs are no worse than that of companies in which training is conducted by external consultants or in-house experts. The results also indicate that training conducted by a collaborative effort between external consultants and in-house experts produced slightly better performance ratings while the accuracy level is lower than that of other groups. There was no obvious indication that training conducted by external consultants or in-house experts resulted in higher MRP performance or accuracy.

The results of these tests indicate that while employee training on MRP systems is related to MRP systems performance, more specific questions need to be tested to determine the amount of training that an organization actually conducts and to evaluate the effectiveness of different training methodologies as they pertain to overall performance.

Hypothesis 6 tested whether **companies that have a quality and performance improvement program like TQM have better performing MRP/ERP systems than companies that do not have such a program**

Of the 76 companies participating in the survey that have MRP/ERP systems, 57 of them claim to have a quality and productivity improvement program like TQM. However, only 10 of these companies had implemented TQM (or a similar quality and performance improvement program) prior to the implementation of their MRP/ERP computer system. The tests do not support that having a quality and productivity improvement program is necessarily associated with higher performance outcomes for MRP systems. While experts in MRP implementation may claim that companies with established TQM programs will have more effective MRP-type systems, these data suggest that not enough companies in this sample population meet the criteria to support this claim.

The questions upon which this statistical analysis was based simply asked whether the organization had implemented a quality and productivity improvement program and in which year the program was established. The effectiveness of the quality and productivity improvement program was not evaluated. The companies were not asked the extent to which their TQM-type program was implemented, and the year that the participant indicated their program was established may be a poor indicator of the extent to which their TQM-type program is influential. A more in-depth study is required to adequately address this issue.

Chapter 5
Conclusions

The objectives of this research were to provide information about current use of MRP-type systems and to identify determinants of MRP/ERP systems performance. These systems originated from the MRP-I systems of the mid-1960's and developed toward broader MRP-II systems. Today, new client-server based enterprise resource planning (ERP) systems are quickly replacing the established MRP-II legacy systems. The ERP systems are linking data for manufacturing resource planning into networked databases such as Oracle and Sybase. These systems allow for information such as component inventory levels in manufacturing to be linked with other functions of an organization such as accounting, and purchasing.

Today's advanced MRP and ERP computer systems are becoming increasingly linked for logistics and supply chain management. In addition, electronic data interchange (EDI) is being increasingly integrated with ERP systems in order to facilitate supplier-customer relationships. These applications provide on-line order processing for data input into advanced systems for manufacturing resource planning. Such accurate, instantaneous information provides actual data for manufacturing management to evaluate production demand and forecast production needs.

The results of this study provide quantitative support for two suppositions that are often mentioned or suggested in technology management. First, upper management support is necessary for effective performance outcomes and second, software customized for individual organizations will perform more effectively than software provided directly from a vendor without customization. Upper management support and knowledge of MRP-type computer systems are strongly correlated with the performance of the MRP systems. However, it is not necessary that the MRP implementation is initiated by top-level management as long as high level support exists for the implementation of the computer system. Furthermore, in these medium to large companies (70% were facilities with more than 300 employees), the results support that upper management involvement improved the accuracy of the MRP system, but not the overall performance.

The hypothesis tests also strongly support that the performance of MRP/ERP systems is higher for organizations that customized vendor purchased software specifically for their organization. The tests also support that the length of time an organization has used MRP-type systems is not related to the performance of the MRP/ERP system. However, the length of time that an organization has used MRP-type systems is highly correlated to the accuracy of the data in the system. The longer an organization has used MRP systems, the more accurate that system tends to be.

The study supports that that the performance of the MRP/ERP system is lower for companies that view system training as an implementation problem. However, differences in training methodology were not determined. Companies that have budgeted for MRP training

did not necessarily perform better that those that had no training budget. Whether or not an organization has a financial budget specified for MRP training may not be a good indicator of the level of MRP/ERP employee training that is conducted. The study did not successfully demonstrate that organizations with strong quality and productivity improvement programs will have higher levels of MRP performance.

5.1. Lessons Learned

Given that I personally had no serious research experience prior to conducting this study, and as in many research projects the original scope of this project was not well defined, many decisions concerning the work was made as information was ascertained and as the project developed.

1. A Sacrifice of Quality or Time- Many of the decisions that I made in regards to this work involved a tradeoff between time allotment and good research methodology. A well conducted survey certainly requires generous time investments as prescribed by Dillman (1978) or Fowler (1988). I was unaware of survey development techniques and the process involved in developing a survey of good quality. However, given my professional work experience, I was also unwilling to mass mail the questionnaire until it had been validated and refined by many other people. Much of my understanding of what needed to be done for the research project came about through trial and error efforts and through in-process research. I looked for books and references on different topics as they were needed and, I sought out experts in specific areas as I needed their expertise.

2. Good research is difficult to do. The majority of the time that I spent on this research project went towards developing a conceptual understanding of what the research will attempt to prove and how to go about doing it. I knew that if I was going to spend my time writing a thesis, I would want to choose a topic that has great mass appeal and practical usefulness. Unfortunately, due to my idealism, I underestimated the effort and personal commitment such a project requires. A mail survey is also highly dependent on the responses of the sample population. This work certainly went over budget in terms of the personal time and work commitment that I had hoped to invest.

3. There are definitely high levels of interest in this topic. I was often surprised by the individuals who voluntarily contributed their time to discuss and review this research with me. More than once, high level managers of large corporations voluntarily met with me for over an hour to discuss the survey and the implementation issues their organizations had experienced with MRP/ERP implementation. The number of survey responses received also indicate that this study addresses issues that are important to industry practitioners.

4. There is value in understanding the integration of multiple functions. The trend of current computer software development is heavily into work process automation and inter-organizational communications (e.g. Lotus-Notes, Microsoft Exchange). Companies are increasingly recognizing the competitive need for investment in integrated enterprise computer systems. In my interviews with current MRP users, it appears to me that effective use of these ERP computer systems will also eventually decrease the workforce required in efficient production and operations management.

5.2. Recommendations

The results of this research and the apparent interest of manufacturing organizations in understanding MRP/ERP performance and implementation certainly justifies additional research in this area.

1. Further justify the performance measures. The performance of the MRP/ERP systems were evaluated on the basis of data accuracy, customer satisfaction, user satisfaction, systems effectiveness, convenience, information relevance, and software reliability. While the questions asked in the survey were appropriate for measuring performance, there appears to be few documented standards for performance measurement of advanced MRP and ERP systems. APICS does have a classification scale for MRP systems based on effectiveness of the system and the level of computerization and integration. Further research related to the integration of ERP systems is certainly valuable to today's manufacturing industries. Future work may involve evaluating the APICS classification system and updating standards to integrate changes related to new ERP systems.

2. Get funding. The level of interest among business professionals in this study certainly indicate that funding mechanisms could be found for this type of research. Studies to document the common implementation problems, issues, and benefits of large computer systems implementation would be beneficial to the management of technology in US corporations.

Future research in this area could justifiably be sponsored by organizations or associations involved in developing standards. In my communications/conversations with APICS, the educational society for resource management, the national Director of the Education and Research foundation mentioned that APICS would seriously consider funding proposals for this type of research if it was conducted for a PhD dissertation. APICS sponsored the landmark Anderson *et al.* (1981) MRP study and, the organization has sponsored several other surveys as well.

3. Further investigate the influence of quality and performance improvement programs on MRP/ERP systems performance. This work did not support that organizations with quality and productivity improvement programs have better MRP-type systems. However, the effect

of quality and productivity improvement programs on MRP systems performance should become more easily justified as a larger number of companies successfully adopt TQM programs prior to MRP-type systems implementation. More descriptive questions may be required to evaluate the strength of the organization's quality and productivity improvement program.

4. Investigate enterprise integration issues. Document situational examples and test prescribed methodology for adapting organizational functions into enterprise resource planning application packages. Often in large computer systems implementation, the question may be asked, "Is the computer system customized to be an effective tool for the operations of the organization, or is the organization adapting to function within the scope of a computer system application?" The computer industry is obviously booming. Yet, are developments in computer applications making significant contributions to the operational effectiveness of organizations?

5.3. Notes for the Practitioner

Throughout this study, MRP users repeatedly cited the "year 2000" problem. Basically, the idea is that essentially all existing mainframe MRP systems will need to be upgraded to newer technology because mainframe systems were not written to handle the four-digit year. Mainframe systems are typically unable to calculate dates past 1999. So, while many companies are still reluctant to adopt newer client/server systems, it would be best for an organization to take a proactive position in implementing advanced MRP or ERP systems if a new MRP/ERP system has not recently been implemented.

Given the cost of today's MRP/ERP systems (easily over $2 million) and the extent to which manufacturing companies will depend on these systems for operations management, it is imperative that there is someone in upper management who is knowledgeable of the company's MRP/ERP system and system needs. This person should be aware of the products currently available to support the company's MRP/ERP system. It is definitely imperative that upper management is supportive of the computer system implementation. In evaluating the effectiveness of your organization's MRP system, consider the entire MRP/ERP system as not only the computer technology, but the people who interface with the MRP system, the operators, the users, and those who update the data.

A project manager who is knowledgeable of the operations associated with manufacturing can best ascertain how MRP software can be customized for an organization. Due to the critical impact of today's MRP systems, it is important to investigate several different systems and develop detailed ideas of what you would like your MRP system to do for your organization. Should technical consultants be hired, ideally the organization would have someone knowledgeable of current systems to direct the work of the consultants.

Some organizations have made MRP/ERP implementation a priority project by forming a cross-functional team to address implementation issues. These teams are assembled to develop an understanding of the different requirements that different functional groups will have of the MRP/ERP system. System requirements may be specified and the team may review software packages being considered for installation. Often these team members will become the key employees in learning and training others on the new system after implementation. Promoting such cross-functional teams demonstrates upper management support for the implementation process. Unlike the many companies of the 1970's that expected MRP to be a problem-solving solution, today's practitioners need to realize that selection, implementation, and the effective use of MRP-type systems involves a multifaceted, often lengthy process. Organizations may not have a choice of whether or not to acquire an MRP-type system if they want to remain competitive. To implement such a system effectively however will ensure a competitive advantage for the organization.

The complexity of today's MRP and ERP systems and the range of the answers provided to this survey questionnaire certainly suggest that the management of these computer systems has yet to be mastered. The performance of current MRP/ERP computer systems is highly dependent upon the integration of this technological system within the social system of the organization.

While MRP-type systems continue to adapt quickly to advances in hardware and computer technology, effective use of these systems need to be continuously re-evaluated. There are nearly one hundred software vendors in the US listed as advanced MRP or ERP software providers. There is a broad range of hardware choices for these systems and limitless application methods for hardware configuration and system architecture. However, the evolving application and effective development of MRP and enterprise resource planning systems will be crucial to the operations of future extended enterprises.

These computer systems, integrated with software for supply chain management, will provide the system that promotes modes of cooperation between organizations within the logistics chain. The effective performance of these integrated enterprise computer systems is crucial to the inter-organizational operations of world class organizations.

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Appendices

Appendix A	**Work Breakdown Structure**
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APPENDIX A

Work Breakdown Structure

A. Background Development
   1. Review literature on MRP systems.
   2. Write Chapter 2 Background
   3. Identify previous surveys conducted on the use of manufacturing computer systems.
   4. Summarize the most relevant studies, include summaries in Chapter 3.

B. Survey Development
   1. Using the results of the 1981 Anderson, Schroeder, et al, APICS sponsored study and the 1991 Sum-Yang, Singapore study, questions were developed to obtain demographic information about current (1996) MRP usage in today's manufacturing company.
   2. Using internet searches, Dr. Roger Schroeder's e-mail address was obtained. In July 1996 an e-mail letter was sent to request a copy of the original 1981 survey. A copy of the original was received by mail from Dr. Schroeder (August 5, 1996).
   3. The survey questionnaire was further modified using the original survey questions.

C. Testing and Refining the Survey
   1. Interviewed the MIS Manager at "Company A", Blacksburg, VA. (Aug. 23, 1996)
      a. Contacted referenced individual and arrange for meeting.
      b. Discussed unclear wording of survey questions.
      c. Discussed the company's use of MRP systems.
   3. Develop hypotheses regarding general factors which are associated with the resulting performance of successfully integrated manufacturing computer systems.
   4. Align survey questions to test the hypotheses.
   5. Interviewed the Chief Information Officer, Company B, Radford, VA. (Sept. 4, 1996)
      a. Obtained introduction to Mr. CIO through a personal acquaintance
      b. Arranged for a meeting.
      c. Introduced the study to CIO, conducted the survey having him answer the questionnaire as a potential survey respondent.
      d. Discussed the wording of specific questions.
      e. Minor changes to the questionnaire were made as a result of his suggestions.
   6. Contact the Master Scheduling Supervisor, Company C, Blacksburg, VA.
      Arrange for meeting with Master Scheduling Supervisor to test survey.
   7. Survey reviewed by Robert E. DeLuryea, IBM consultant via e-mail.

D. Obtain and Prepare Mailing List
   1. Obtained initial contacts for local chapters of IIE and APICS.
      a. a list of the regional IIE chapter presidents was provided by IIE regional Vice President.
      b. a list of the regional APICS chapter presidents can be found on APICS' internet web page.
   2. Telephoned regional presidents to request a copy of their chapter membership lists. Left messages when necessary.
   3. Due to "privacy issue" as noted by the Tri-Cities APICS chapter,
      contacted national Director of APICS' Education and Research Foundation. A formal letter requesting the use of the APICS membership list was faxed and mailed Sept. 12, 1996. By phone on Sept 16, Mr. Lythgoe noted that APICS may be able to provide re-printed mailing labels for the study.
   4. Need to finalize agreement for using APICS mailing labels.

E. Obtain approval for use of human subjects
   1. Contact department representative to the Internal Review Board for use of human subjects
      a. Obtain forms to request approval for use of human subjects
      b. Obtain example of prepared request
   2. Prepare request for use of human subjects (including informed consent statement)
   3. Submit request (Aug. 29, 1996) and obtain approval (received Sept. 5, 1996)
   4. Prepare informed consent statement to distribute with survey questionnaires

F. Establish the statistical analysis to be performed
   1. Arrange for statistical consulting with the Statistical Consulting Service, VT statistics department. (Sept. 2, 1996)
   2. Met with Dr. Schulman and graduate student, Angela Kennedy (Sept 4, 1996), reviewed survey, obtained advice on statistical analysis methodology.
   3. Met with PhD student, Yu-Haur Lee (Sept. 15, 1996), further discussed pairwise statistical tests that could be used to test the hypotheses.
   4. Prepare detailed plan to test hypotheses 2-5, meet again with Dr. Schulman and Angela Kennedy (Also, David Burt) to finalize statistical tests to be used (Sept. 23, 1996).

G. Prepare Surveys for Mass Mailing
   1. Obtain membership list/mailing labels from Mike Lythgoe, national APICS
   2. Verify as much as possible that the targeted survey recipient has a job title that most likely will involve working with MRP-type computer systems
   3. Add names from local IIE membership lists that were obtained
   4. Check to make sure that only one survey will be mailed to each organization.
   5. Prepare all mailing labels.
   6. Prepare final survey packet
      a. prepare and print survey summary request cards for survey participants
      b. print final copies of the survey
      c. print informed consent forms
      d. prepare complete survey packets and postage required
      e. stuff envelopes and mail

H. Collect survey responses
   1. Receive surveys in daily mail Oct. - Nov. 1996
   2. Compile summary list of survey responses using Microsoft Excel.
   3. Summarize list of additional handwritten survey responses notes.

I. Validate performance measurement rating method.
   1. Meet with statistical consultants to conduct preliminary tests on evaluation methodology.
   2. Perform prelimnary principle components analysis.
   3. Validate methodology with Dr. Robert Schulman.
   4. Perform principle components analysis with complete data set.

J. Perform Statistical Analysis.
   1. Summarize basic demographics statistical data on organizations using MRP.
   2. Prepare spreadsheets with data for hypothesis tests.
   3. Perform statistical tests using Minitab 10.5.
   4. Document statistical tests performed.
   5. Validate statistical results and terminology with statisticians.
   6. Finalize written statistical tests.

K. Summarize the results and establish conclusions that are supported by the survey responses.

APPENDIX B

Informed Consent

Effective Use of MRP-Type Computer Systems to Support Manufacturing

Patty W. Cheng, graduate student

I. Purpose of this Project

This study is being conducted to investigate the current use of Manufacturing Resource Planning type computer systems in today's manufacturing industry. The availability of such information will enable organizations to develop methods to more effectively use computer systems to support manufacturing operations and to better integrate MRP-type systems into the business processes of the organization. This research will seek to identify the common experiences of companies that have implemented MRP and to determine factors that lead to the successful application of these systems.

II. Procedure

The survey will be mailed to approximately 200 companies in western Virginia that most likely have MRP systems. The list of potential survey recipients is developed from the membership lists of local chapters of the American Production and Inventory Control Society and the Institute of Industrial Engineers. In order to collect data about the characteristics of manufacturing companies currently using MRP-type applications, only one survey will be sent to an organization. If you are not directly involved with the MRP system in your company, please pass on this survey packet to the resident MRP expert in your organization. If your company does not use a MRP-type system, please complete questions 1-8 of part one only and return the survey.

It is estimated that the survey will take the you approximately 30 to 40 minutes to complete. Please answer all the questions completely or provide a best guess answer if you can. Return the survey in the prepaid envelope by October....., 1996. *(* within 3 weeks of receipt or 4 weeks after the day they are mailed out.)*

III. Risks

Participation in this study will pose no risk to you.

IV. Benefits of this Study

Although there is no financial compensation associated with participation in this study, participation in the survey provides an opportunity to increase your understanding of the issues that contribute to the success of MRP-type systems. If you return the "Summary Request Card" with the completed survey, a copy of the survey summary report will be mailed to you upon completion of the study.

V. Extent of Anonymity

Your participation in this study will be kept confidential. For data analysis, all survey responses will be coded with a unique number which will not be used to identify you. The numeric code may be used to determine the percentage of non-responding survey recipients and to prevent replication of data being used in the analysis.

VI. Compensation

Unfortunately, no financial compensation can be awarded for participation in this study. However, this study is designed to increase your understanding of success factors that influence MRP performance within organizations. An increased understanding of MRP performance factors may very likely benefit your work with MRP systems in future endeavors.

VII. Freedom to Withdraw

Survey recipients may choose not to participate in the study if they so wish. Participants may choose not to answer certain survey questions if they do not understand or do not wish to respond to certain questions. Participants are encouraged to answer all the questions or provide their best guess answer to a question. It is asked that no more than two questions in the survey be left intentionally unanswered.

VIII. Approval of Research

This research project has been approved by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Department of Industrial and Systems Engineering.

IX. Subject's Responsibilities

I voluntarily agree to participate in this study. I have no specific responsibilities as a result of this participation.

X. Subject's Responsibilities

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

_____ _____

Signature Date

Should I have any questions about this research or its conduct, I may contact:

Patty W. Cheng (540) 552-4335 [EMAIL: pcheng@mail.vt.edu]

Dr. C. Patrick Koelling (540) 231-7286

E.R. Stout (540) 231-9359
Chair, IRB
Research Division

Appendix C

The Survey

Survey of Computer Systems Usage in Manufacturing

The questions in this survey are designed to be answered by the MIS Manager, Materials Manager, Master Scheduler, Production and Inventory Control Manager, or another person who is most familiar with the MRP or manufacturing related computer system in your company. If you encounter questions that you cannot answer or questions which do not apply to your company, please leave them blank. Answer the remaining questions by filling in the blank, or circling or checking the most appropriate response. When you have completed the questionnaire, please return it in the prepaid return envelope. If you would like to receive a copy of the results of this study, please return the summary request card with your completed survey. Thank you for your help.

Part I
Demographics & Organizational Characteristics

1. In which industry would you classify your organization? (check all that apply)

   ( ) Electronic products and components
   ( ) Fabricated metal products
   ( ) Electrical machinery, apparatus, appliances, or supplies
   ( ) Machinery and Transport Equipment
   ( ) Pharmaceutical or Chemical products (including cosmetics, paints)
   ( ) Paper products
   ( ) Plastic products
   ( ) Food packaging
   ( ) Instrumentation Equipment
   ( ) Textile
   ( ) Other _____

2. What is your job function? (check one)

   ( ) Materials Management
   ( ) Inventory Control Management
   ( ) Scheduling (Master Schedule)
   ( ) MIS Management
   ( ) Production Management
   ( ) Other _____

Please describe, in the remainder of the questionnaire, the manufacturing computer system for the facility with which you are most familiar or for which you are responsible.

3. The facility described in the remainder of this questionnaire is:

   a) A single plant
   b) Part of an company with several plants
   c) Other (describe) _____

4. How many people work at your plant site?

   a) Less than 100 people
   b) Between 101 and 300 people
   c) Between 301 and 600 people
   d) Between 601 and 1000 people
   e) More than 1000 people

5. What is the average **annual sales** revenue of your company? (circle)

Total Company	Under $20 million	$21-50 million	$51-100 million	$101-200 million	over $200 million
Your Facility or Organizational group	Under $20 million	$21-50 million	$51-100 million	$101-200 million	over $200 million

6. How many different unique computer application packages are currently used to monitor, schedule, plan, and report the status of manufacturing production processes within your facility or operational division?

   (a) 0 (b) 1 (c) 2 (d) 3 (e) 4 (f) 5 (g) 6 (h) 7 or more

7. What type of computer hardware is used by your organization to support manufacturing? (circle all applicable)

   a) mainframes
   b) minicomputers (including workstations)
   c) networked personal computers
   d) stand-alone personal computers.
   e) other _____

8. Does your company currently have or is your company currently implementing a MRP (Manufacturing Resource Planning) or ERP (Enterprise Resource Planning) computer system?
   a) Yes
   b) No

If the answer to question number 8 is "No" then please stop here and return this questionnaire. Thank you for your participation.

9. How do you define the term "MRP" ? (circle one)

   a) A computerized materials/production planning and control system for production only.
   b) Primarily computerized materials/production planning and control system integrated with other business areas to achieve a total business system.
   c) General system for computerizing any business function
   d) Other _____

10. What was the source of your MRP system?

    a) Developed internally within your organization
    b) Vendor supplied with little or no modifications
    c) Vendor supplied with some modifications
    d) Vendor supplied with major modifications

11. In what year did your company first install a MRP system? _____

12. In what year was your current MRP system installed? _____
If your organization is currently implementing a new system, for which year is the installation scheduled to go on-line?

13. Who initiated MRP development in your company?

a) Top management
b) Production and inventory control management
c) Both top management and production and inventory control management
d) Information systems
e) Software and hardware vendors
f) Other (describe) _____

14. Which of the following was used to install MRP in your company? (If more than one system has been installed, base your answer on the most recent installation attempt.)

a) A formal project was established with a project manager, budget and staff
b) A less formal project planning group was organized
c) An individual was assigned the responsibility
d) Other (describe) _____

15. To what extent is someone in upper management involved with implementing the MRP system?

a) Not at all
b) Slightly involved
c) Moderately involved
d) Highly involved

16. To what extent is a high-level manager knowledgeable of computer systems.

a) Not at all
b) Slightly knowledgeable
c) Moderately knowledgeable
d) Highly knowledgeable

17. To what extent does top management support the implementation and project management of the MRP computer system?

a) Very little or Not at all
b) Limited support
c) High level of support
d) Entirely support

18. In terms of hardware, software, and external technical service, how much has your organization invested in MRP systems?
a) Less than $500,000
b) $500,000 or more and less than $750,000
c) $750,000 or more and less than $1,000,000
d) $1 million or more and less than $2 million
e) Two million dollars or more

19. Indicate the additional investment your organization plans to spend on MRP hardware, software, and external technical service in the next 3 years.
    a) Less than $ 50,000
    b) $ 50,000 or more and less than $ 200,000
    c) $ 200,000 or more and less than $ 500,000
    d) $ 500,000 or more and less than $ 1,000,000
    e) One million dollars or more
    f) Don't know / undefined

20. In terms of the total cost of your MRP system, what percentage of the total cost would you expect to be allotted
    for

Hardware:	_____ %	
Software:	_____ %	
External Technical Services:	_____ %	
Other _____	_____ %	
Total	*100%*	*Note: Total should sum to 100%*

21. Were MRP users within your company involved in the selection of the MRP software prior to implementation?

    a) No
    b) Yes, internal users provided some input for the software selection.
    c) Yes, internal users were heavily involved in software selection.

22. Training on the existing MRP system is conducted by

    a) external consultants, MRP computer systems specialists
    b) in-house experts, employees involved with implementation
    c) there is no formal training program, training is done on-the job with experienced employees
    d) other (describe) _____

23. Does your company have funds dedicated to training employees on the use of MRP-type computer systems, post installation?

    a) Yes
    b) No

24. Does your company have a Quality or Productivity Improvement Program such as TQM?

    a) Yes
    b) No
    c) It was attempted

25. If your company does have a Quality or Productivity Improvement Program, in what year was it or is it being implemented?

    a) _____ (year)
    b) No such program exists

Part II
Usage of MRP-type System

A. MRP system features (please fill in the blanks)

1. How many end items are produced in your plant? (approximately) _____
2. How many component parts are produced in your plant? (approximately) _____
3. How many levels are used in your computerized Bill of Materials system ? (on average) _____
4. How is your MRP system updated?

a) Net change
b) Regenerative (e.g. weekly replanning cycles)
c) Both
d) Other _____

5. How often is your Master Production Schedule updated?

a) Weekly
b) Daily
c) Other _____

B. Answer the following group of questions by circling the number at the right of each question, using the scale below:

0 = Not at all
1 = 1 - 20 %
2 = 21 - 40 %
3 = 41 - 60 %
4 = 61 - 80 %
5 = 81 - 100 %

To what degree is your organization currently computerized to support these functions?
(circle one for each function)

	0%	**1-20%**		**41-60%**		**81-100%**
1. Inventory management/ Inventory Stock System	0	1	2	3	4	5
2. Bill of Materials	0	1	2	3	4	5
3. Purchasing and receiving	0	1	2	3	4	5
4. Materials requirement planning	0	1	2	3	4	5
5. Accounts payable/Accounts receivable	0	1	2	3	4	5
6. Cost Accounting	0	1	2	3	4	5
7. Sales order processing/ Order entry and invoicing	0	1	2	3	4	5
8. Routing/work centers	0	1	2	3	4	5
9. Payroll/personnel	0	1	2	3	4	5
10. Master production schedule	0	1	2	3	4	5
11. Shop floor control	0	1	2	3	4	5
12. Detailed operations scheduling	0	1	2	3	4	5
13. Capacity requirements planning	0	1	2	3	4	5
14. Forecasting End Items	0	1	2	3	4	5
15. Sales analysis	0	1	2	3	4	5
16. Product Data Management	0	1	2	3	4	5
17. To what degree are the different functions of your MRP systems integrated?	0	1	2	3	4	5

C. Within the next 2 years, in which of the following areas do you expect your organization to be further computerized? Please provide an estimate based on your experience and your knowledge of the organization.

0 = No additional computerization effort expected.
1 = Additional, though minimal computerization development expected.
2 = Some computerization effort is expected.
3 = Significant computerization in this area is anticipated.

	None	Minimal	Some	Significant
1. Inventory control / Inventory management	0	1	2	3
2. Bill of materials	0	1	2	3
3. Purchasing and receiving	0	1	2	3
4. Materials requirement planning	0	1	2	3
5. Accounts payable/Accounts receivable	0	1	2	3
6. Cost Accounting	0	1	2	3
7. Sales order processing/ Order entry and invoicing	0	1	2	3
8. Routing/work centers	0	1	2	3
9. Payroll/personnel	0	1	2	3
10. Master production schedule	0	1	2	3
11. Shop floor control	0	1	2	3
12. Detailed operations scheduling	0	1	2	3
13. Capacity requirements planning	0	1	2	3
14. Forecasting	0	1	2	3
15. Sales analysis	0	1	2	3
16. Product Data Management	0	1	2	3

D. From the experience your organization has had with MRP systems, rate the following benefits of MRP systems using the following scale:

0 = No Benefit
1 = Low Benefit
2 =
3 = Moderate Benefit
4 =
5 = High Benefit

	None	Low		Moderate		High
1. Better meeting of delivery dates	0	1	2	3	4	5
2. Better production scheduling	0	1	2	3	4	5
3. Better ability to meet volume/product changes	0	1	2	3	4	5
4. Better Cost Estimation	0	1	2	3	4	5
5. Improved productivity	0	1	2	3	4	5
6. Lower Inventory Costs	0	1	2	3	4	5
7. Shorter Delivery Lead Time	0	1	2	3	4	5
8. Increase Throughput	0	1	2	3	4	5
9. Reduced safety stocks	0	1	2	3	4	5
10. Improved competitive position	0	1	2	3	4	5
11. Other _____	0	1	2	3	4	5

E. From the experience your organization has had with MRP systems, rate the following *implementation problems* using the following scale:

0 = No Affect, Not Applicable (N/A)
1 = Small Problem
2 =
3 = Moderate Problem
4 =
5 = Large Problem

	N/A	Small		Moderate		Large
1. Lack of top management support	0	1	2	3	4	5
2. Lack of suitability of software	0	1	2	3	4	5
3. Lack of support from vendor	0	1	2	3	4	5
4. Lack of clear goals for the MRP effort	0	1	2	3	4	5
5. Lack of company expertise in MRP	0	1	2	3	4	5
6. Lack of training/education on MRP	0	1	2	3	4	5
7. High cost of MRP system	0	1	2	3	4	5
8. Lack of communication within organization	0	1	2	3	4	5
9. Lack of information technology expertise	0	1	2	3	4	5
10. Other _____	0	1	2	3	4	5

Part III
System Effectiveness and User Satisfaction

A. What is the accuracy of the following types of data in your MRP-type system? (circle one for each)

	Poor (0-80 %)	Fair (81-90 %)	Good (91-95 %)	Excellent (96-100 %)	Not Applicable
1. Inventory Records	1	2	3	4	x
2. BOM Records	1	2	3	4	x
3. Market Forecasts	1	2	3	4	x
4. Master Production Schedule	1	2	3	4	x
5. Production Lead Times	1	2	3	4	x
6. Vendor Lead Times	1	2	3	4	x
7. Shop Floor Control Data	1	2	3	4	x
8 Capacity Plan	1	2	3	4	x

B. Please answer the following group of questions by circling the number at the right of each question, using the scale below:

1 = Strongly Agree (SA)
2 = Agree (A)
3 = Agree Somewhat (AS)
4 = Do not Agree or Disagree (N)
5 = Disagree Somewhat (DS)
6 = Disagree (D)
7 = Strongly Disagree (SD)

	SA	A	AS	N	DS	D	SD
1. The information available in your MRP system is relevant for making decisions.	1	2	3	4	5	6	7
2. It is convenient to obtain information from your MRP system.	1	2	3	4	5	6	7
3. Your MRP software is reliable.	1	2	3	4	5	6	7
4. You are able to do a more effective job than you would be able to do without your MRP system.	1	2	3	4	5	6	7
5. Using your MRP system improves your job performance.	1	2	3	4	5	6	7
6. Using your MRP system improves the performance of your organization.	1	2	3	4	5	6	7
7. Your MRP software is not dependable.	1	2	3	4	5	6	7
8. The use of your MRP system improves the control over your organization's assets such as inventory, and accounts receivable.	1	2	3	4	5	6	7
9. Satisfaction of your customers has increased due to the use of your MRP system.	1	2	3	4	5	6	7
10. Your ability to perform work is not helped by your MRP system.	1	2	3	4	5	6	7
11. The use of your MRP system has provided information to allow you to make better decisions.	1	2	3	4	5	6	7
12. Overall, you are satisfied with your MRP system.	1	2	3	4	5	6	7

Thank you for your participation. Please return the questionnaire ASAP in the prepaid return envelope. Remember to return your summary request card with your survey if you would like to receive a copy of the results of this study.

Appendix D & E

Letter of Request for APICS mailing list

Survey Cover Letter

Thurs., Sept. 12, 1996

Mr. Mike Lythgoe, Director
APICS
Education and Research Foundation
500 W. Annandale Road
Falls Church, VA 22040

Dear Mr. Lythgoe,

As I indicated in our phone conversation, I am a graduate student in Industrial and Systems Engineering at Virginia Polytechnic Institute in Blacksburg, Virginia. I am currently working to complete my Master's Thesis on "Effective Use of MRP-type Computer Systems to Support Manufacturing." This research involves conducting a regional survey to collect current (1996) data about how MRP-type (including ERP) computer systems are actually being used in today's industry. A copy of the survey is included with this letter. (I reserve the right to adjust the wording of survey questions prior to the final survey printing if necessary.)

Much of this survey was developed from the results of the 1981 APICS sponsored study conducted by Anderson, Schroeder, Tupy and White. Dr. Roger Schroeder sent me a copy of their 1981 questionnaire earlier this year. Other questions in the survey are based on the 1992 Sum-Yang, Singapore study that was developed with assistance from Anderson and Schroeder. I have also added questions to measure the accuracy of MRP systems, user satisfaction, and user perceptions of systems performance. Other questions address the level of top management support for systems implementation, the degree of external technical expertise involved with implementation, and types of user training techniques.

I would like to formally request that APICS allow me the use of your local membership lists The study is targeted for the central to western Virginia and eastern Tennessee areas. As for the scope of this study, I would like to identify approximately 200 MRP users as potential participants. I intend to use your list(s) to develop my own MRP user mailing list. In order to evaluate characteristics of organizations using MRP systems, only one survey questionnaire will be sent to each company.

The results of the study will be mailed to all participants who request a copy and, I would certainly be glad to make it available to APICS as well. Thank you very much for your assistance, and I look forward to hearing from you in the near future.

Sincerely,

Patty W. Cheng

cc: Dr. C. Patrick Koelling

Enclosures: (1) Survey of Computer Systems Usage in Manufacturing
(2) Virginia Tech- Institutional Review Board Protocol Report

Tues., Oct. 22, 1996

Dear

Computer Systems to support manufacturing have evolved tremendously within the last 20 years. Many companies such as yours have implemented or are currently in the process of implementing Manufacturing Resource Planning and Enterprise Resource Planning type computer systems in order to meet the production needs of today's markets. While many significant financial decisions have been made with respect to the capital investment necessary for these potentially large computer systems, there has been little in the way of formal studies to determine to what extent and how industries are actually using these MRP-type computer systems.

As a member of APICS, you have been selected as an individual who may very likely use an MRP-type computer system in your work. The targeted participant list for this study was provided by the Education and Research Foundation of APICS. Mr. Mike Lythgoe, Director of the APICS Education & Research Foundation has approved the use of APICS membership for this study. Your participation in this study is critical in order for the results of this study to truly indicate what type of industry benefits most from MRP systems, and to obtain a representative picture as to what extent MRP-type systems are being used in manufacturing today.

In order to evaluate characteristics of organizations using MRP systems, only one survey questionnaire is being sent to your company. There was no specific methodology used to select the targeted participant, though job titles were used to some extent. If there is someone else in your organization who you believe would be better suited to describe your organization's MRP system, please encourage them to answer the questionnaire.

You may be assured of complete confidentiality. The questionnaire has an identification number for mailing purposes only. This is so that we may check your name off the mailing list when your questionnaire is returned. Your name will never be placed on the questionnaire. Please complete and return the questionnaire within the next 3 weeks.

The results of the study will be mailed to all participants who request a copy. There is a green summary request card enclosed in this package. If you would like a copy of the survey results, simply enclose the green card with the complete survey. Please also review, sign, and return the "Informed Consent" information sheet about the survey. This sheet is included as a requirement of Virginia Tech.

I would be most happy to answer any questions you might have. Please call, write, or e-mail me. My telephone number is (540) 552-4335 and my e-mail address is [*pcheng@mail.vt.edu*].

Thank you very much for your assistance.

Sincerely,

Patty W. Cheng
Principal Investigator

C. Patrick Koelling, PhD

Appendix F

Survey Responses

The answers to the survey are compiled in this summarized survey responses table. The survey respondent code or "participant" number is listed in the first (left) column. Individual questions for each participant are listed along the top row, and the corresponding answer for each question can be found in the intersecting block. An "x" indicates the answer was left blank or unanswered. In question 5T (Total) and 5F (Facility), "less than $20 million" is coded as "1" while "greater than $200 million" is coded as "5."

Additional comments written in by survey respondents are noted with asterisks (*); the comments are provided at the end of the spreadsheet in column "* notes" and "** notes." More detailed comments provided by survey respondents are noted after the spreadsheet in the "survey responses notes." The keys for responses recorded to survey questions 1 and 2 are listed below.

Key to Question 1 Responses (Industry)

EC	Electronic products and components
FM	Fabricated metal products
EM	Electrical machinery, apparatus, appliances, or supplies
MT	Machinery and Transport Equipment
PC	Pharmaceutical or Chemical products (including cosmetics, paints)
PA	Paper products
PL	Plastic products
I	Instrumentation Equipment
T	Textile

Key to Question 2 Responses (Job Function)

mm	Materials Management
icm	Inventory Control Management
s	Scheduling (Master Schedule)
mis	MIS Management
pm	Production Management

Sumarized Survey Responses

Particip	Ques. 1	2	3	4	5T	5F	6	7	8	9	10	11	12	12x	13	14	15	16	17	18	19	20a	20b	20c	20d	21
0.1	EC,FM,EM	mis- sr. mg	b	c	5	3	d	bc	a	b	c	84	97	97	ab	a	d	d	d	e	b	33	33	34		c
0.2	EM	s	b	c	5	4	b	a	a	b	d	80	80		c	a	b	b	c	e	d	x	x	x		c
1	EC	mm	b	e	5	3	h	ac	a	b	d	87	87	97	a	d*	a	a	b	e	f	25	30	45		a
7	automotive compo	MIS	b	c	5	3	c	bcd	a	b	d	91	94		d	c	a	a	a	a	a	30	50	20		b
12	PL, rubber, compo	o-adm mgt	a	c	5	2	c	bc	a	a	d	94	94		a	a	d	d	d	a	b	10	40	50		c
13	furniture	s	b	b	1	1	b	b	a	b	a	94	94		a	b	c	d	c	a	a	x	x	x		c
15	Wood Furniture, h	icm	b	e	3	2	h	abc	a	b	a	64	64		a	b	b	c	c	d	a	80	20	0		a
23	EC	planner	a	c	x	2	b	ac	a	b	d	x	x		a	x	b	c	c	x	x	x	x	x		x
29	FM	icm	b	e	5	5	h	abcde*	a	b	d	85	87		c	a	c	c	c	d	f	5	12	10	73*	c
34	PC	mm	b	e	5	5	b	a	a	b	c	85	85	98	c	a	d	c	c	c	e	20*	70	10		c
35	PA	s	b	b	x?	2	c	ac	a	b	d	84	94		a	b	b	b	b	b	b	x	x	x		a
36	EM	buyer	b	b	3	2	x	a	a	a	b	96	96		c	a	c	c	c	a	b	x	x	x		a
38	EC	icm	b	d	5	4	c	ac	a	b	d	92	92		b	c	b	d	d	a	a	0	100	0		a
45	PA	icm	b	b	4	2	b	c	a	b	c	95	95		c	b	b	b	b	a	b	40	40	10	10	a
51	PL,T,medical hom	mm	b	d	5	5	e	abcd	a	a	c	78	85		c	b	c	b	c	a	e	25	50	10	15*	a
52	MT	pm	b	b	1	1	c	bd	a	b	a	77	77*	98	c	c	c	d	c	a	c	x	x	x		a
53	PC	icm	b	c	5	5	h	acd	a	b	d	84	84		c	b	a	b	a	e	e	10	70	20		b
56	automotive*	mm	b	c	3	3	c	acd	a	b	d	90	90		c	b	c	c	c	a	f	40	40	20		b
58	EC,FM,EM, PL,sm	icm	b	e	5	x	e	ac	a	x	b	91	91		ade	a	c	d	c	e	e	35	35	10	20	a
60	EC	pm- mfg m	a	a	1	1	b	bcd	a	b	b	86	92		a	c	b	c	d	a	b	10	80	10		c
61	T	proj. leadr	b	e	5	4	d	b	a	b	c	92	92		a	a	c	c	c	c	b	50	40	10		c
62	FM, MT	mm	b	c	4	3	b	b	a	b	c	87	97		c	b	d	c	b	b	e	30	40	30		a
64	T	mm	a	d	5	3	d	ad	a	a	a	95	95		b	b	a	b	a	a	a	70	30	0		b
69	PC	mm	b	e	5	5	b	abc	a	b	d	85	85		b	a	b	b	c	d	f	40	40	20		c
70	FM	mm	b	b	5	3	h	a	a	b	a	72	80	97	b	b	b	c	c	d	f	40	30	30		b
71	FM,MT	mm	b	c	4	2	c	ac	a	b	c	92	92		a	a	c	c	c	b	b	30	40	30		b
73	I	mm	a	c	3	3	b	ad	a	b	d	79	79		b & d	b	b	c	c	c	e	60	20	20		a
74	EC,I	mm	b	d	5	4	d	acd	a	d*	a*	95-tr	98		f**	b	b	b	a	d	e	30	40	20	10	a
77	PA, folding carton	icm, mis	b*	e	5	5	f	abcd	a	b	a**	96	96	96	b	a	c	b	c	d	e	25	25	50		c
81	T	icm	b	b	5	5	f	acd	a	b	c	?	?		x	x	c	c	b	?	f	20	40	40		?
82	MT	icm	b	b	5	3	b	bc	a	b	b	77	95		ad	a	d	d	d	d	c	30	60	10	x	c
83	FM	pm	b	b	x	x	b	abcd	a	b	d	82	82	97	d	a	d	c	d	e	e	20	70	10		b
84	FM	mis	b	d	5	4	b	bc	a	b	b	80	93		c	b	c	c	c	e	f	49	49	2		c
86	MT	mm	a	c	5	4	b	ac	a	b	d	74	90		c	a	c	b	a	d	c					b
90	EC	mm	b	c	5	1	c	abc	a	b	a	x	x	98	c	a	c	d	c	d	f	30	45	25		x
93	EC, EM	mm	a	c	5	x	h	bcd	a	b	c	81	81		abcd	a	b	c	c	x	f	x	x	x		c
101	Automotive OEM	logistcs, op	b	e	5	5	d	abc	a	b	d	89	92	98	b	a	b	a	a	d	f	40	40	20	0	c
103	PL	mm,s	b	e	5	5	h	a	a	c	c	96	96		x	b	a	a	a	e	f	x	x	x		a

Sumarized Survey Responses

Particip	22	23	24	25	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	C1	C2	C3	C4	C5
0.1	ab	a	a	91	2000	1000	5	c	a	4	4	4	4	4	4	4	4	4	3	3	2	2	1	3	0	3	3	3	3	3	3
0.2	c	b	a	91	2000	1500	1.5	b	b	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0
1	d*	b	c	94	450	0	40	c	a	5	5	5	x	4	4	5	3	5	5	3	3	0	0	0	1	5	1	1	1	1	0
7	c	b	b	b	300	500	9	c	b	2	3	1	1	3	1	4	1	4	0	0	0	0	1	2	2	1	3	2	3	3	2
12	ab	b	a	90	500	2000	4	b	b	4	5	3	4	5	5	5	5	1	4	2	3	1	5	1	5	4	2	1	3	2	1
13	b	a	a	95	300	4000	3.5	x	5	5	5	5	5	5	5	5	5	5	5	4	4	4	0	3	3	4	2	0	0	2	0
15	c	b	c	b	1450	20K+	3	b	a	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	2	1	1	1
23	c	b	a	96	300	150	5	b	a	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	0	0	0	0	2
29	x	b	a	94	300	75	2	c	b	3	4	4	3	4	3	3	4	3	3	3	2	3	3	4	3	3	3	1	2	2	2
34	a&b	a	a	95	600	3000	2	b	a	5	5	5	5	5	5	5	3	5	5	3	3	4	4	5	5	4	2	1	1	3	1
35	b	b	b	b	4800	800	2	c	b	5	5	5	5	5	5	5	5	5	5	5	5	3	5	3	3	5	0	0	0	0	0
36	b	b	b	b	200	20000	x	b	a	5	5	5	5	5	5	5	5	5	5	5	3	0	3	5	3	3	2	2	2	2	2
38	b	a	a	91	20	40	18	c	c-m	5	5	5	4	5	5	5	5	5	5	3	2	0	1	1	5	4	0	0	0	0	0
45	a	a	b	b	x	x	4	b	c	3	4	5	2	5	4	5	4	0	3	4	0	0	3	4	3	x	3	3	3	3	3
51	c	b	a	90	1200	600	2	b	a	5	5	5	5	5	4	5	3	5	4	3	3	4	4	4	4	3	1	1	2	3	1
52	c	b	a	90	30	10000	5	c	c-m	5	5	3	3	5	4	2	4	5	4	2	2	2	2	1	2	1	1	1	1	2	1
53	c	b	a	95	x	x	3	b	b	5	5	5	5	5	5	5	1	5	5	1	1	5	5	5	5	4	2	1	1	1	0
56	b	a	a	90	4000	10000	4	c	b	5	5	5	4	4	4	5	5	5	4	3	3	2	3	4	4	3	2	1	1	2	1
58	ab	a	a	90	300	1000	x	b	a- s	5	5	4	4	4	x	4	3	5	5	x	4	2	3	2	4	4	3	2	1	2	1
60	c	b	a	96	1750	30000	6	a	a	5	5	2	2	3	4	2	2	2	2	3	0	0	0	0	0	1	1	1	2	1	2
61	b	b	a	95	6500	11000	3	a	a	5	5	3	5	5	3	5	5	5	3	3	4	3	2	3	3	5	1	1	2	2	0
62	ab	a	b	b	7	10K	9	b	o	5	5	5	5	5	4	5	5	5	5	3	3	3	0	3	2	5	1	2	3	2	2
64	c	b	b	b	25000	60000	2	b	a	5	2	3	4	1	0	0	0	1	0	0	0	3	0	1	1	3	2	2	3	2	2
69	b	b	b	b	500	200	3	b	b	5	5	5	5	4	5	5	3	3	5	3	5	4	5	4	4	5	0	0	0	0	2
70	b	b	a	90	10	400	6	b	a	5	4	5	5	3	4	5	4	5	4	4	1	1	4	4	0	4	2	3	2	3	3
71	c	b	a	96	5	2500	4	b	a	4	3	4	4	5	5	3	4	5	4	2	3	3	2	2	2	2	2	3	2	2	1
73	b	a	a	83	6000	12000	5	b	c-m	4	5	5	5	4	5	4	0	4	4	1	1	0	4	3	4	4	3	3	3	3	2
74	c	b	c	94	100+	20000	6	b	na	3	2	3	2	2	1	2	2	3	0	2	1	0	0	0	3	1	3	3	2	3	2
77	b	x	a	91	4000	10000	4	a	b	2	2	2	1	4	2	2	1	4	1	1	1	1	0	0	0	0	3	3	3	3	3
81	c	b	a	a?	30K sku	x	4	d*	b	4	5	4	3	5	5	5	4	5	3	3	2	2	0	1	2	2	3	2	2	3	1
82	b	b	a	90	300	7000	4	c	a	5	5	5	5	5	5	5	5	0	2	4	3	2	1	0	0	4	3	3	3	3	3
83	b	b	a	96	6000	50	2	c	a	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	3	3	3	3	3
84	d*	a	a	92	4000	500	3	c	b	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	0	1	0	0
86	c	b	a	92	3000	13000	4	b	c-m	5	5	4	5	5	5	5	5	5	5	3	x	2	4	x	x	5	1	0	3	2	2
90	b	a	a	94	3000	500	2.5	c	b	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	1	1	1	1	1
93	a	a	a	70	450	0	3	c	a	5	5	5	4	5	5	5	3	5	5	3	5	5	5	5	4	5	3	3	3	3	3
101	c	b	a	93	350	100	18	a	b	5	5	5	5	5	5	5	0	5	5	5	0	0	4	1	1	5	**New system Planned				
103	b	b	a	92	700	0	1	b	c-m	2	2	2	2	4	4	5	0	0	1	4	0	0	3	5	0	2	3	3	3	3	1

Sumarized Survey Responses

Participnt	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
0.1	3	3	3	3	3	3	3	3	3	3	3	4	4	4	2	2	3	3	3	3	2	x	5	3	3	3	5	4	4	3	3	x
0.2	0	0	0	0	0	0	0	0	0	0	0	5	5	5	5	4	4	5	5	5	4	x	1	1	1	0	0	0	0	0	0	x
1	0	1	3	3	1	2	0	0	0	0	0	4	4	5	5	4	3	2	2	2	3	x	5	3	2	3	0	1	1	3	1	x
7	1	3	3	3	0	3	0	0	3	3	2	1	1	1	1	1	1	1	1	1	1	x	5	5	5	5	5	5	5	5	1	x
12	1	1	1	2	1	2	3	3	1	1	1	4	3	3	2	3	4	5	5	3	3	x	0	0	1	1	4	2	0	2	4	x
13	2	1	2	1	1	2	2	2	2	2	2	5	5	3	3	4	1	3	4	0	4	x	1	3	0	2	2	2	0	1	2	x
15	1	1	1	1	1	1	1	1	1	1	2	5	4	4	4	3	5	3	3	4	2	x	1	1	2	3	3	4	1	2	3	x
23	2	0	3	2	0	0	0	0	0	1	0	5	5	5	3	3	3	4	3	4	4	x	1	0	3	2	3	5	3	4	1	x
29	1	2	1	1	2	2	2	1	1	1	1	3	4	4	2	2	4	2	2	4	3	x	1	4	2	5	4	3	4	4	2	x
34	2	3	2	1	2	3	3	3	3	1	1	4	4	4	3	4	3	4	3	4	4	x	1	2	1	3	2	2	1	3	3	x
35	0	0	0	0	0	0	0	2	0	2	2	4	4	3	4	3	4	4	3	2	2	x	5	5	2	2	2	4	5	3	3	5*
36	2	2	2	2	2	2	2	2	2	2	2	3	4	3	2	4	4	4	4	4	3	x	1	1	2	3	3	3	2	2	2	x
38	0	0	0	0	2	0	0	0	1	0	0	5	5	5	0	4	5	5	4	5	5	x	2	1	3	1	1	1	0	0	0	x
45	3	3	3	3	3	3	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	x	4	4	4	4	4	4	3	3	3	x
51	3	0	1	0	2	1	1	2	1	1	1	2	3	2	1	1	2	0	1	0	1	x	2	3	5	2	3	4	2	4	5	x
52	1	3	1	1	2	1	2	2	2	2	2	3	4	4	2	3	3	3	3	3	3	x	0	0	0	0	0	0	4	2	0	x
53	0	3	2	0	1	2	2	2	1	2	2	2	3	4	4	3	2	4	2	2	2	x	2	1	3	4	1	2	1	5	1	x
56	1	1	1	1	1	2	1	1	1	2	1	4	4	4	3	4	4	3	4	3	3	x	2	3	2	3	4	3	3	4	3	x
58	x	2	2	1	2	2	2	3	2	2	2	1	0	0	1	1	1	1	1	0	0	x	0	0	2	3	4	3	0	2	1	x
60	2	2	2	3	1	3	3	2	2	2	2	1	1	0	1	0	1	1	1	1	1	x	0	3	5	1	0	0	5	0	0	x
61	3	1	2	0	2	2	2	2	1	2	2	5	4	4	3	4	4	5	4	4	5	x	1	0	0	1	2	1	2	3	1	x
62	3	3	2	1	3	3	3	3	3	3	3	5	4	4	5	5	5	4	5	4	5	5*	5	3	2	5	4	5	1	5	4	x
64	2	1	1	1	1	0	0	0	1	0	0	4	4	3	1	1	4	2	2	3	2	x	4	3	2	4	4	4	3	5	3	x
69	0	0	2	2	0	1	0	1	1	1	1	4	4	4	5	4	4	3	4	3	3	X	1	1	0	0	0	1	0	1	0	X
70	3	3	3	3	3	3	3	3	3	3	3	5	5	4	4	4	4	3	4	3	4	x	2	1	2	2	4	3	2	2	2	x
71	1	1	2	1	1	2	2	2	1	1	1	4	4	4	4	4	4	4	4	4	4	X	4	2	3	3	5	4	3	5	3	x
73	2	3	2	2	3	3	2	1	2	2	2	4	4	4	2	3	4	3	3	3	4	0	5	4	2	2	3	3	4	4	3	0
74	3	2	2	1	3	2	3	3	2	2		3	5	3	3	4	3	4	1	2	1	5**	5	3	2	5	3	5	3	5	2	x
77	3	3	3	3	3	3	3	3	3	3	3	Not applicable, no current experience											Currently Implementing									
81	1	1	1	1	3	2	3	3	2	1	2	2	2	3	4	2	3	3	3	3	3	x	N/A Implemented before I was employed here.									
82	3	3	3	0	3	3	3	3	3	3	3	3	3	3	2	3	5	3	3	3	3	x	1	1	1	1	1	1	1	3	1	x
83	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	x	1	3	3	4	2	3	1	4	3	x
84	0	1	0	0	0	0	2	1	2	2	2	4	3	4	4	2	3	4	2	2	4	x	4	0	4	2	0	1	2	3	1	x
86	2	2	3	2	1	3	3	3	2	x	x	4	2	3	4	4	4	5	5	x	5	x	3	2	1	3	3	4	x	5	1	x
90	1	1	1	1	1	1	1	1	1	1	1	5	4	4	3	3	5	5	4	5	5	x	0	1	0	0	0	0	1	0	0	x
93	3	3	3	3	3	3	3	3	3	3	3	5	5	5	3	4	4	5	3	4	4	x	1	1	1	1	1	1	1	1	1	x
101	I to Replace existing sytems							0 or 3?				3	4	3	4	4	3	3	3	3	2	x	5	1	3	5	5	5	3	4	3	x
103	2	3	0	0	3	3	0	2	3	3	3	3	3	0	0	0	2	2	0	1	0	x	5	3	1	4	4	4	1	5	5	5*

P.Cheng 12/96

Sumarized Survey Responses

Participnt	A1	A2	A3	A4	A5	A6	A7	A8	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
0.1	2	2	1	1	1	2	2	1	6	6	6	4	4	4	3	6	6	3	4	5
0.2	4	4	2	3	3	3	3	4	1	1	1	1	1	1	7	1	1	7	1	1
1	2	3	1	2	2	3	1	1	2	1	1	1	1	1	7	2	3	7	2	1
7	1	3	1	1	1	1	1	1	7	4	7	4	7	7	1	7	7	1	7	7
12	3	4	x	3	2	2	2	2	1	1	3	1	1	1	7	1	1	7	1	1
13	x	3	x	3	3	3	2	x	2	1	2	1	1	1	5	1	1	7	2	3
15	3	4	3	3	4	2	4	2	1	2	1	2	2	2	7	2	4	6	2	2
23	3	2	2	4	3	3	3	3	2	2	2	1	1	1	6	3	2	6	2	2
29	1	1	2	3	3	3	2	2	2	4	4	2	4	4	4	3	4	6	3	5
34	3	4	1	3	3	3	2	2	2	2	2	1	2	2	6	2	2	6	2	2
35	3	2	1	3	3	3	3	1	1	1	2	1	1	3	6	1	5	7	1	2
36	3	3	3	3	3	3	4	2	2	2	2	2	2	1	6	2	2	6	2	2
38	4	3	2	4	2	3	1	1	1	2	2	1	1	1	7	1	1	7	1	1
45	1	2	1	1	2	2	2	1	5	5	5	3	5	4	4	4	5	4	3	5
51	4	4	3	3	3	2	1	2	3	5	3	2	3	3	5	3	4	4	3	3
52	4	3	2	3	3	2	3	4	2	3	3	1	2	2	6	2	2	6	2	4
53	3	4	1	1	2	3	1	1	2	2	2	1	1	2	6	2	3	7	2	2
56	2	3	1	2	2	2	1	1	2	2	2	2	2	2	4	2	3	5	2	3
58	2	1	1	x	2	1	3	1	2	3	3	3	4	3	6	6	4	5	5	5
60	2	3	1	1	1	2	3	1	3	2	4	5	4	4	4	3	4	4	3	4
61	4	3	2	2	3	3	2	2	2	2	3	1	2	1	6	2	2	6	2	2
62	2	1	1	1	2	2	1	1	5	4	4	1	1	1	5	1	2	6	2	6
64	4	2	2	2	3	2	1	1	2	1	1	1	1	2	6	4	4	5	1	4
69	4	4	3	4	4	3	3	4	1	1	1	1	1	1	7	2	2	7	1	1
70	4	3	2	2	3	3	2	2	2	3	2	2	2	2	6	3	3	6	2	3
71	3	2	1	2	2	2	2	2	2	2	3	2	2	2	5	2	2	6	2	3
73	2	1	1	3	3	3	x	x	1	2	2	1	1	2	5	2	3	5	2	3
74	2***	2	1	1	1	1	2	1	2***	7	3	6	6	6	4	6	7	3	6	6
77	1***	1	1	2	1	1	1	1	1	1	2	1	1	1	7	1	4	1	1	1
81	2	3	1	1	1	1	2	2	5	6	4	3	4	4	4	6	5	3	5	5
82	1	4	1	1	4	4	3	2	2	2	2	1	1	1	7	1	3	7	1	1
83	4	4	2	2	4	3	4	3	1	3	1	1	1	1	7	1	1	6	2	2
84	3	4	1	2	2	3	3	2	3	2	1	1	2	2	7	2	3	6	3	3
86	1*	3	x	3	3	3	1	1	1	1	1	1	1	1	6	2	2	6	2	2
90	3	4	2	3	4	3	4	2	1	1	2	1	1	1	6	2	2	6	2	2
93	3	3	3	3	3	3	3	3	1	1	1	1	1	1	6	3	3	6	3	2
101	1	3	2	3	x	4	3	1	3	3	2	2	3	3	4	1	3	2	6	3
103	1	1	1	1	2	3	1	1	5	7	6	5	5	5	7	6	6	1	4	7

Participnt	*notes	** notes
0.1		
0.2		
1	*project mgr & staff- no budget!	** external consultant leads, utilizing in-house "super users"
7		
12		
13		
15		
23		
29	* contract programmers	7e- various other process control & data acquisition computers from IBM, DEC & HP
34	* May be more due to required hardware change	
35	* Prob- Resistance to change	
36		
38		
45		
51	*Education & Training	
52	77* with gradual evoluation	
53		
56	*rubber coated steel auto gaskets	
58		
60		
61		
62	* Benefit - See Note 7 - S_R_NTS	
64		
69		
70		
71		
73		
74	Note 5 - S_R_NTS	**Benefit- Information is easier to obtain. ***Based on home grown system
77	* consumer packaging division - 8 plants in US	** Note 4 - S_R_NTS *** III-A based on currently unintegrated system (don't use!)
81	*Not currently using MRP for Planning /Scheduling	** Note 3 - S_R_NTS
82		
83		
84	*orig MRP training done in house using Ollie Wight tapes.	
86	* Note 1 - Survey_ResP_NoTeS	
90		
93		
101	*New system Planned to Replace existing sytems	
103	* Prob- Don't understand what system can do and will do for us.	

Sumarized Survey Responses

Particip	Ques. 1	2	3	4	5T	5F	6	7	8	9	10	11	12	12x	13	14	15	16	17	18	19	20a	20b	20c	20d	21
104	T	mis	b	e	5	3	e	abd	a	b	b	x	97		d	c	b	b	c	d	d	30	60	10		b
112	FM,MT	icm	b	c	5	4	b	ac	a	a	c	85	92		c	a	c	c	d	d	c	20	50	30		a
114	Flat Glass	mm,ic,s	b	e	5	5	h	bc	a	a	a	81	92		c	a	d	d	d	e	e	50	38	12		c
117	FM	mm	b	b	5	1	b	acd	a	b	b	72	89		c	a	d	d	d	e	f	40	30	30		c
125	automotive-brakin	mm	b	b	5	3	c	abc	a	b	a	78	93		bd	a	b*	d	b	b	c	20	80			c
130	FM	mm	a	b	x	2	b	c	a	b	c	86	95		c	a	c	b	d	a	b	30	50	20	LAN	c
133	PC	s	b	d	5	5	b	bcd	a	b	d	82	93		a	a	d	d	d	x	x	x	x	x		b
140	MT	pm	b	c	x	5	h	a	a	b	d	80	80		c	a	c	c	d	e	e	x	x	x		b
141	FM, commercial c	mm	c- si	b	2	2	b	a	a	a	c	79	79		c	b	a	a	b	a	b	0	75	25	x	a
146	MT	mm	a	c	4	3	b	abcd	a	b	c	87	87		c	a	c	b	d	x	x	60	30	10		b
149	FM,PL,I	mm	a	c	4	4	h	acd	a	b	c	82	93		c	a	b	a	b	e	e	33	34	33		b
151	FM	mm	b	e	5	5	c	ac	a	b	c	78	91	97	c	a	c	d	c	d	e*	20	75	5		b
152	FM	mm	a	b	1	1	c	cd	a	b	c	x	x	97	c	b	b	b	b	a	a	20	60	20		b
158	Fiberglass Boats	mis	b	e	5	x	b	cde,mi	a	a	a	88	88		b	a	c	c	d	d	e	20	80	0		c
159	Automotive supplie	mm	a	d	4	4	b	ad	a	b	c	88*	88		d	c	b	b	b	a	b	50	40	10		a
160	FM,MT	mis	b	c	5	5	d	abc	a	b	c	80	90		c	a	b	c	c	c	e	20	50	30		c
164	FM, aerospace mf	mis	a	e	4	4	h	abcd	a	b	d	88	88	98	a	a	c	c	c	e	e	10	50	40	c	ab
170	F	icm	b	b	5	2	c	acd	a	a	d	88	88		d	a	b	b	b	e	f	40	50	10		a
171	PC	mm	b	b	3	2	c	ac	a	b	b	90	96		b	a	c	c	c	d	c	30	40	30		c
174	FM	mm	a	b	5	3	b	acde. F	a	b	c	92	92		c	b	c	c	c	e	e	50	20	30		c
176	PA,giftwrap, ribbo	mm	b	c	4	x	c	acd, rft	a	b	d	93	93		c	a	d	c	d	d	f	75	25	0		a
177	FM,EM	mm	b	e	5	5	c	abcd	a	b	d	87	87		a*	b	b	b	b	e	e	30	30	10	30**	a
187	EM	mm	b	b	5	2	c	ac	a	b	c	?	95		c	b	b	d	c	a	b	40	50	10		a
197	FM, automotive su	mm.icm,s,	b	e	5	5	h	abcd	a	b	d	71	*		bde	a	b	a	b	d	d	40	40	10		b
207	PC	s	a	d	3	3	b	ab	a	a	c	90	90		c	a	b	c	b	a	d	75	25	0		a
215	EC	mm	a	e	5	5	b	a	a	b	a	91	91		c	a	c	c	d	c	b	25	60	15	0	b
216	EM	mm	b	b	3	3	c	ac	a	b	c	95	95		c	a	c	c	c	a	b	50	50	0		b
218	PA	s	b	d	5	4	c	c	a	x	b	87	96		d	a	b	b	c	d	d	x	x	x		b
219	EM	mm	a	c	5	3	h	a	a	a	d	80	93		a	a	c	c	c	e	e	x	x	x		b
221	EC	s	b	d	5	3	b	bc	a	b	b	92	92		c	a	c	b	c	b	b	40	35	20	5	b
224	T	mis	a	b	5	2	h	c	a	b	b	94	94	97	a	b	b	b	b	a	f	30	5	40	25*	a
228	PL	plant mgr	b	b	4	2	d	ad	a	b	c	91	96		c	a	c	b	c	b	c	x	x	x		a
229	PL	mm	b	b	5	3	h	bc	a	b	d	78	91	97	c	a	b	c	b	e	d	0	0	100		b
238	PL,Automotive	purchasing	b	c	3	3	c	ac	a	b	c	82	97		abcd,	a	d	c	c	a	c	40	50	10		c
239	Transportation	mm	c-co	e	5	x	c	acd	a	b	d	84	84		b	a	b	c	c	e	f	0	60	30	10	b
240	MT	mm	a	b	2	x	b	a	a	b	b	90	90		b	c	a	c	c	a	a	50	50	0		b
242	EC	mis	b	b	3	2	b	b	a	b	b	87	92		a	a	d	c	c	c	c	30	50	10	10*	a
246	EC	icm	b	d	5	4	b	abc	a	b	c	82	92		bd	b	a	c	b	d	d	35	59	15		a

Sumarized Survey Responses

Particip	22	23	24	25	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	C1	C2	C3	C4	C5
104	c	a	c	96	60000	100K	10	b	a	3	3	3	3	4	3	4	3	4	1	1	1	0	0	2	1	1	3	3	2	3	2
112	b	a	a	85	300	5400	5	b	a	5	5	5	5	5	5	5	5	5	5	4	4	4	5	5	5	5	1	1	2	1	1
114	c	b	a	78	50	0	1	a	c-as	5	4	5	3	5	5	5	5	5	4	4	5	5	3	4	3	1	2	0	1	2	1
117	b	b	a	91	100	50	x	b-da	a	4	5	4	5	3	5	5	4	0	5	0	x	0	5	4	5	5	0	0	0	0	1
125	b	a	a	94	500	1000	7	b	a	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	1	1	1	1	3
130	b	a	b	b	1300	700	2	a	b	5	5	5	5	5	3	5	5	0	5	5	5	2	2	2	0	5	1	1	2	2	0
133	b	a	b	b	300	50	5	a	a	5	5	5	5	5	5	5	5	5	5	5	5	4	4	4	5	4	0	0	0	0	0
140	a	a	a	86	25	3000	3	b	a	3	5	5	5	4	4	5	5	5	5	3	2	3	3	3	3	4	3	3	3	3	3
141	c	b	b	b	850	35000	7	b	c-m	5	5	3	5	0	3	0	5	0	5	0	0	0	0	0	0	3	3	1	3	3	2
146	c	b	a	90	150	1000	2	x	c-m	5	5	3	5	4	4	5	0	4	3	0	0	3	4	5	3	3	2	1	1	2	1
149	c	b	b	b	15000	2000	2	b	c-m	5	5	5	5	5	5	5	5	4	5	5	3	3	5	5	4	4	2	1	2	2	1
151	b	a	a	91	75	300	4	b	a	5	5	5	5	5	5	5	5	5	5	3	3	2	4	4	5	3	3	3	3	3	3
152	b	a	a	92	1500	5000	4	c	a	5	0	1	4	4	4	3	0	4	5	0	0	0	0	2	2	0	3	2	3	3	3
158	b	a	a	92	50	2000	2	b	a	5	5	5	5	5	2	4	0	4	5	0	0	0	0	4	3	5	3	3	2	2	1
159	c	b	a	88	500	200	5	b	b	4	5	5	5	5	4	5	5	3	4	3	3	4	4	3	5	4	1	1	2	1	1
160	c	b	a	90	60	3000	4	b	a	4	5	5	4	5	5	4	4	4	4	2	0	2	2	2	4	2	3*	3	3	3	3
164	a	c	b		25	5000	8	a	c*	5	5	5	5	5	5	4	5	5	5	5	5	5	5	4	4	0	3	3*	3	3	3	3
170	c	a	c	92	100	200	6	b	a	5	5	4	5	4	2	5	0	4	4	0	4	0	3	4	2	3	0	1	1	2	1
171	a	a	b	b	750	100	3	b	a	5	5	5	5	5	4	5	5	3	5	3	0	0	5	5	5	3	3	3	3	3	3
174	c	b	a	94	4000	2000	3	c	b	3	5	4	5	5	4	4	5	3	5	4	5	4	2	4	3	5	2	1	1	1	1
176	b	a	b	b	2000	20000	5	b	b	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	2	1	3	1	2
177	c	b	a	93	400	500	7	b	a	5	5	5	5	5	5	5	5	5	5	3	4	3	5	5	5	5	3	1	1	1	1	1
187	b	b	c	a	300	50	5	b	c-m	5	5	4	4	5	4	5	4	5	3	0	0	0	1	0	3	4	1	1	2	2	1
197	ab	a	a	94	800*	8000	5	b	a	3	5	5	5	5	5	5	3	5	5	2	1	2	3	2	??	4	3***	3	3	3	3
207	c	b	b	b	10000	1000	1	b	a	5	5	5	5	5	5	5	5	5	0	5	0	0	0	0	0	3	0	0	0	0	0
215	b	b	a	92	325	275	6	b	a	5	5	5	5	5	5	5	0	5	5	0	0	0	0	0	5	4	0	0	0	0	0
216	a	a	a	96	1000	10000	6	b	a	5	5	5	5	5	5	5	5	5	5	5	3	0	5	4	4	5	0	0	0	0	0
218	b	b	a	93	1000	20K	5	b	c- 2	5	5	5	5	5	5	5	5	5	5	5	3	3	5	3	3	5	0	0	0	0	0
219	a	b	a	93	500	300	7	d-re	c-m	5	5	4	5	5	5	5	5	5	5	2	2	3	1	1	1	x	x	x	x	x	x
221	b	a	a	91	8	25	2	b	a	3	2	5	4	5	4	4	5	5	3	5	4	4	2	2	2	4	1	2	1	1	2
224	b	b	c	b	250	2000	5	d**	yet	5	2	0	0	4	2	4	1	5	0	0	0	0	0	0	4	0	2	3	3	3	3
228	b	a	c	94	x	x	x	x	a	x	4	0	5	5	5	5	0	0	5	0	0	5	5	5	0	3	3	3	3	3	3
229	b	b	a	95	1000	0	1	x	c-m	0	1	4	1	5	1	5	1	4	1	0	0	0	1	1	1	1	3	3	3	2	3
238	b	a	a	94	2000	200	3	d	c	4	5	5	1	3	2	5	2	4	0	2	0	1	5	5	4	1	3	2	2	1	3
239	a	a	a	80	x	x	2	c	c	5	3	5	4	4	3	3	0	0	0	0	0	0	4	0	0	4	2	1	2	0	1
240	b	a	a	91	150	1000	4	b	a	5	5	5	5	5	5	5	5	4	5	4	3	3	1	4	5	41	1	1	1	1	1
242	b	a	a	93	45	25	3	c	b	5	5	5	4	5	4	5	0	0	3	0	0	0	2	4	3	5	0	0	0	0	0
246	a	b	b	b	1000	15000	7	b	a	5	5	5	5	5	5	5	5	5	5	4	4	4	5	3	3	5	x	x	3	x	x

Sumarized Survey Responses

Participn	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
104	3	3	3	1	3	3	3	3	2	3	2	1	1	1	1	1	1	1	1	1	1	x	5	3	3	5	5	5	3	5	4	x
112	1	1	0	0	0	2	2	3	2	2	2	5	5	5	5	5	5	5	5	5	5	x	0	0	0	0	0	0	1	0	1	x
114	1	2	2	2	2	2	2	2	1	1	1	5	5	5	3	5	5	5	4	5	5	x	0	5	1	4	4	4	2	5	5	x
117	1	3	1	0	0	0	0	1	1	1	1	4	4	3	1	3	2	3	4	4	2	x	1	2	0	1	1	2	5	3	2	1
125	1	1	1	1	1	1	1	1	1	1	1	5	5	5	4	5	5	5	5	5	5	x	5	1	2	1	1	1	1	1	1	x
130	3	1	1	0	1	1	1	3	1	1	1	5	4	4	4	4	4	4	4	4	4	x	1	3	3	2	1	2	4	2	3	x
133	0	0	0	0	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	x	0	2	1	1	3	3	2	3	3	x
140	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	x	4	4	4	4	4	4	4	4	4	x
141	2	2	3	2	3	3	3	3	2	2	2	5	5	3	1	5	4	4	3	5	3	x	3	3	2	3	4	5	3	5	4	x
146	1	2	1	1	1	0	0	1	1	3	2	4	5	4	2	3	4	4	4	3	3	x	1	4	2	1	2	1	1	2	1	x
149	1	1	1	1	2	2	3	3	1	2	2	3	3	4	3	3	4	3	3	3	3	x	4	5	5	3	1	1	4	4	2	x
151	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	3	4	4	4	4	4	x	2	2	3	2	3	3	2	3	3	x
152	3	3	2	3	3	3	3	3	3	3	3	5	5	2	2	4	3	4	4	3	4	x	2	3	4	2	1	2	3	2	2	x
158	2	2	2	3	2	2	2	1	1	2	3	4	1	4	1	4	4	3	3	4	2	x	1	1	0	1	4	4	1	4	1	x
159	1	2	1	2	1	2	1	1	1	1	1	5	5	4	3	2	4	4	4	3	3	x	4	3	2	3	2	2	2	2	2	x
160	3	3	3	1	3	3	2	3	2	3	3	4	3	3	3	3	3	4	4	4	4	x	3	3	1	4	4	4	1	3	2	x
164	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3	3	5	5	4	5	5	x	3	3	4	3	2	2	4	5	2	x
170	3	1	0	3	1	0	1	2	0	1	1	2	2	0	2	1	3	1	3	3	2	x	3	5	4	3	4	3	4	4	2	x
171	3	3	3	3	3	3	3	3	3	3	3	4	4	4	5	4	5	4	4	4	4	4*	5	3	3	2	2	3	4	4	5	x
174	1	3	1	2	1	2	2	1	1	2	1	4	4	3	3	3	3	4	3	4	4	x	4	2	5	3	3	2	2	5	3	x
176	2	2	1	2	1	1	1	1	3	3	1	5	5	4	3	5	5	3	3	5	3	5*	1	3	3	1	4	4	1	3	3	x
177	1	1	1	2	1	2	1	2	2	2	2	3	4	3	2	3	3	3	2	2	1	x	5	3	2	5	5	5	2	5	5	x
187	2	1	1	2	2	1	1	2	2	1	1	4	3	4	3	4	4	3	3	3	3	x	1	2	0	0	0	1	0	1	1	x
197	3	3	2	2	3	2	1	2	2	1	?	4	2	3	2	2	3	2	3	3	3	5**	4	1	2	3	1	0	0	2	0	x
207	0	0	0	0	3	3	3	3	3	3	3	3	1	2	3	2	2	0	0	0	0	x	3	5	5	2	3	4	4	1	5	x
215	0	0	3	0	0	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	5	4	x
216	0	0	0	0	0	0	2	3	0	2	2	4	4	4	3	4	5	4	3	4	3	x	1	4	3	0	3	3	0	1	3	x
218	0	0	0	0	0	2	2	2	0	0	0	3	3	5	3	3	3	5	5	3	5	x	3	3	2	1	1	3	5	3	3	x
219	x	x	x	x	x	x	x	x	3	3	3	5	5	5	1	4	4	4	4	4	4	x	3	4	4	4	4	4	4	4	4	x
221	2	1	1	1	2	1	2	2	1	2	1	3	4	2	2	3	2	3	3	2	2	x	3	2	2	3	4	4	3	4	4	x
224	3	3	3	2	3	3	3	3	3	3	3	Not applicable											4	2	1	5	5	5	1	5+	1	4***
228	3	3	3	3	3	3	3	3	3	3	3	3	5	3	5	5	4	3	5	5	5	x	5	4	3	5	4	4	3	5	5	x
229	2	3	1	2	1	2	0	0	2	2	2	3	3	3	2	2	2	2	2	2	2	x	5*	5	5	5	5	5	5	1	4	x
238	3	2	3	2	1	2	0	1	3	1	2	1	1	0	1	0	0	0	0	0	0	*	5	5	4	2	1	3	5	5	2	x
239	1	0	0	0	0	0	0	0	1	0	0	3	0	1	0	2	2	1	0	1	0	x	1	4	2	2	4	1	3	1	2	x
240	1	1	1	2	2	2	2	2	3	2	1	4	4	5	4	4	4	4	4	5	4	x	3	3	3	4	4	4	3	3	5	x
242	0	0	1	0	1	0	1	1	1	2	1	4	1	1	5	3	5	2	3	4	3	x	0	1	1	4	5	0	0	2	0	0
246	x	x	x	x	x	3	3	3	3	x	x	4	4	4	3	4	4	4	4	4	4	x	2	1	1	2	1	3	1	3	3	x

Sumarized Survey Responses

Participnt	A1	A2	A3	A4	A5	A6	A7	A8	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
104	1	1	1	1	1	1	1	1	5	6	6	4	4	4	3	5	4	3	4	5
112	4	4	2	4	4	4	3	2	1	2	2	1	1	1	7	1	1	7	1	1
114	4	x	x	4	4	x	4	4	1	3	2	1	1	1	7	1	1	7	1	1
117	3	4	1	4	2	2	1	1	2	3	3	1	2	2	7	2	2	7	2	2
125	4	4	2	3	4	3	4	3	1	3	4	1	1	1	3	1	1	7	1	2
130	4	3	1	2	2	2	3	2	1	2	2	1	1	1	2	1	1	1	1	2
133	3	4	3	3	3	3	3	3	1	2	2	1	1	1	6	2	2	6	1	x
140	3	3	3	3	3	2	2	2	4	3	3	1	2	2	4	3	2	2	3	4
141	2	4	1	3	2	3	x	x	2	3	1	1	1	1	7	1	1	7	2	2
146	3	2	2	3	2	2	x	3	3	6	2	1	2	2	6	2	2	7	2	2
149	2	3	3	3	2	2	4	1	3	3	7	3	5	6	1	7	6	5	3	7
151	3	4	2	3	3	3	2	2	2	2	1	3	2	2	7	3	3	6	3	2
152	3	x	x	3	2	3	x	x	2	5	2	2	2	2	6	2	4	6	2	3
158	3	2	x	4	4	3	x	x	1	1	1	1	1	1	7	1	4	7	1	1
159	3	4	4	4	x	x	3	4	1	1	2	1	1	1	6	2	4	6	1	2
160	2	3	2	2	2	2	2	2	2	4	3	2	4	3	6	2	3	6	3	3
164	4	3	x	3	2	2	3	2	1	5	2	1	1	1	6	2	2	7	1	2
170	3	4	1	2	3	3	x	x	3	2	3	2	2	2	4	2	4	3	2	7
171	4	4	2	4	3	3	4	3	2	3	5	2	2	2	4	2	2	6	2	2
174	4	4	2	4	4	3	3	4	2	3	2	1	1	1	6	1	1	6	2	2
176	4	4	2	2	3	2	4	4	1	2	3	1	1	1	5	1	1	7	2	2
177	2	3	2	3	2	2	1	1	1	1	5	2	1	2	3	3	2	6	2	3
187	4	3	1	2	x	4	x	x	1	1	2	1	1	1	6	1	2	6	1	2
197	3	4	3	3	4	4	2	3	2	3	2	1	2	2	7	3	2	6	2	2
207	3	3	x	1	1	1	1	1	7	2	2	2	2	2	2	3	6	5	3	2
215	4	4	1	4	4	4	1	1	1	1	1	1	1	1	7	1	1	7	1	1
216	2	3	3	2	3	3	4	x	1	2	3	1	1	1	5	1	4	7	1	5
218	2	2	1	2	2	2	3	x	2	2	1	2	2	2	5	3	2	5	2	2
219	4	4	x	3	4	4	2	1	2	3	5	7	2	2	3	3	3	7	3	4
221	2	3	1	2	3	3	4	4	3	2	2	1	2	2	6	3	4	5	2	3
224	3	2	x	x	1	x	2	x	1	4	5	4	4	2	6	4	4	4	4	4
228	3	3	3	3	3	x	x	3	2	4	2	5	2	4	5	5	5	5	4	4
229	2	1	1	2	2	2	1	2	2	6	6	3	3	3	3	3	4	4	3	6
238	1	1	x	x	4	4	1	1	6	7	7	7	7	7	1	2	7	1	7	7
239	2	3	x	x	x	1	x	x	4	5	4	2	5	6	5	5	6	4	5	5
240	4	3	2	3	3	3	3	2	2	2	2	1	1	1	6	2	2	6	2	2
242	4	3	1	2	4	3	1	1	1	1	1	1	1	2	7	1	4	6	2	2
246	4	3	2	4	2	3	2	2	3	2	3	1	2	2	6	1	3	5	2	2

Sumarized Survey Responses

Participnt	*notes	** notes
104		
112		
114		
117		
125	*Upper mgt, slightly involved - a mistake!	
130		
133		
140		
141		
146		
149		
151	* next 3 yr invstmt - $5.5 million	
152		
158		
159	* MRP began w/ startup of company	
160	* A new ERP system will be installed	
164	*based on chgs in custmr delivery requirements	**entirely new system bein installed throught out the enterprise
170		
171	* Benefit - Customer Service	
174		
176	* Inventory Accuracy	
177	* management of parent company	** Education & Training
187		
197	*ongoing upgrades **division level	*** will put in new software in 1-3 years ** Benefit- Less Manual Effort : Note 6
207		
215		
216		
218		
219		
221		
224	* Inhouse Tech Svc **Still implementing	***Prob- Lack of Managemt training & education toward MRP
228		
229	*Ques answered from division, not single plant perspective	** Root cause of all other problems
238	* I obviously do not support MRP	
239	*Note- this seems like an unusual case.*	
240		
242	* Training /Education	
246		

Sumarized Survey Responses

Participnt	Ques. 1	2	3	4	5T	5F	6	7	8	9	10	11	12	12x	13	14	15	16	17	18	19	20a	20b	20c	20d	21
8	T	o-corporat	b	b	4	3	f	ac	b																	
21	replacemt filters fo	mm							b	* We mfg a limited num of replacement filters for a few utilites, but do not track them																
24	Government Consulting, distribution center - Omit this recd								b																	
25	FM	pm,mm	b*	b	2	2	b	b	b		*company w/ 2 plants, just beginning search (for system) as of last week															
33	MT	pm	b	d	5	4	c	bcd	b	a	c	96	96	96	c	b	b	b	d	a	a	0	100	0		a
96	MT, Marine Engin	mm	a	b	4	3	g	abc	b																	
111	automotive	mm	b	d	5	3	d	ac	b																	
128	Other	other	a	a	1	1	b	d	b																	
132	FM,MT	mm	b	c	3	x	c	c	b																	
154	Consumer Markin	mm	b	b	5	2	d	c	b																	
155	FM,Ordinance	mm	a	a	1	1	d	d	b																	
183	Don't have MRP system currently but will begin implemetaio								b																	
185	US Postal Service	mm	not applicable						b																	
202	EC	s	a	b	5	5	h	ad	b																	
209	Printing	s	b	c	3	3	c	bcd	b																	
231	FM	mis	b	e	x	5	c	ac	b																	
241	FM	s	a	a	1	1	b	bc	b																	

Sumarized Survey Responses

Participnt	22	23	24	25	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	C1	C2	C3	C4	C5
8																															
21	n on MRP/ERP																														
24																															
25																															
33	b	a	b	b	1000	0	5	b	a	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	0	0	0	0
96																															
111																															
128																															
132																															
154																															
155																															
183																															
185																															
202																															
209																															
231																															
241																															

Sumarized Survey Responses

Participnt	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
8																																
21																																
24																																
25																																
33	0	0	0	0	0	0	0	0	0	0	0	MRP being installed, not yet on line.													5				Don't use the rema			
96																																
111																																
128																																
132																																
154																																
155																																
183																																
185																																
202																																
209																																
231																																
241																																

P.Cheng 12/96

Sumarized Survey Responses

Participnt	A1	A2	A3	A4	A5	A6	A7	A8	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
8																				
21																				
24																				
25																				
33	aining data																			
96																				
111																				
128																				
132																				
154																				
155																				
183																				
185																				
202																				
209																				
231																				
241																				

Sumarized Survey Responses

Participnt	*notes	** notes
8		
21		
24		
25		
33	* Note 2 - S_R_NTS	
96		
111		
128		
132		
154		
155		
183		
185		
202		
209		
231		
241		

Survey Responses Notes

Note 1 (from participant #86, Ques III-A1):

Inventory accuracy involves the human factor. This ...depends on communicating to the handlers & production people the importance of perfoming the necessary transactions. The system is only as good as the discipline of the people using the system, output directly related to input.

Ques I-19
additional investment - Because of inability of system to handle yr. 2000 and corporate dictates to expand system.

Note 2 (from participant #33, Ques II-D to end):

MRP not yet on line.

At times through this survey I was not clear as to what you were referring to in regard to MRP & MRP system.

Ex. "MRP" to me is a material requirements planning software. It is a "scheduling" function.
We have an integrated software system which includes many modules of which "MRP" is one.
An "MRP System" is "MRP" as defined above, however there seemed to be blurred lines b/t an integrated system & "MRP."

Note 3 (from participant #81):

Implementation complete before I came here. MRP used mostly as a BOM (Bill of Materials) explosion. Modules used to plan/ schedule work are currently disabled. Most planning/ scheduling done on PC spreadsheets.

Note 4 (from participant # 77):

Paper products - Folding Carton Manufacture, Consumer Packaging Division - 8 plants in US.

Source of MRP system Ques. # I-10
Current- developed internally w/in organization
In process of implementing vendor supplied system with no major mod. (b)

Note: Little modification in MRP software, yet 13 people are working full time on the implementation project (?)

Part II-C note - Current project underway to implementa SSA's BPCS . 13 full time on project.
Part III-A based on the current unintegrated system.
Part III-B expected through prototyping

* Please feel freee to call if you have questions I am the implementation manager for our BPCS implementaion.

Note 5 (from participant # 74):

Background of company. We currently are using a home-grown, modular software package based on organizational structures.

1995/96 we were attempting to implement a software package that was not supported by top management. Also, this software is not a good fit for our industry type.

1996-1997 we are investigating another software package that our parent company has used. This scenerio has obviously influenced my answers to your questions.

Part I-9 * MRP is an environment/behavior demonstrated by all employees, the software is secondary.
Part I-10 Source of current MRP system a) Developed internally within organization Currently implementing Vendor supplied system w/ major modifications, Reviewing other options.
**I-13, initiated by one former owner, no longer with company

Note 6 (from participant # 197):

We use repetitive shop floor scheduling & supplier releases, NOT work orders or purchase orders. This is typical of the automotive industry.

Note 7 (from participant # 62):

Part IID - #11 Other Benefit - Establish foundation of knowledge to move toward contemporary productive processes which expand employee involvement.

APPENDIX G

PRINCIPLE COMPONENTS ANALYSIS

This test indicate there is only one primary dimension in the weighted values for the data set. (See page 56)

The SAS System 15

Principal Component Analysis

75 Observations
12 Variables

Simple Statistics

	B1	B2	B3	B4
Mean	5.773333333	5.213333333	5.253333333	6.080000000
StD	1.484818065	1.678909985	1.619921030	1.458988913

	B5	B6	B7	B8
Mean	5.866666667	5.813333333	5.346666667	5.520000000
StD	1.518652793	1.512947127	1.623254433	1.596956565

	B9	B10	B11	B12
Mean	4.920000000	5.400000000	5.600000000	4.986666667
StD	1.633765341	1.700556348	1.414213562	1.720255585

The SAS System 17

Principal Component Analysis

Correlation Matrix

	B1	B2	B3	B4	B5	B6
B1	1.0000	0.5834	0.5860	0.4950	0.6816	0.6607
B2	0.5834	1.0000	0.6208	0.6163	0.7215	0.6703
B3	0.5860	0.6208	1.0000	0.6488	0.7280	0.6922
B4	0.4950	0.6163	0.6488	1.0000	0.7551	0.7354
B5	0.6816	0.7215	0.7280	0.7551	1.0000	0.9301
B6	0.6607	0.6703	0.6922	0.7354	0.9301	1.0000
B7	0.5545	0.3940	0.7113	0.5473	0.5562	0.5935
B8	0.5576	0.5478	0.5700	0.6315	0.7422	0.7566
B9	0.6275	0.5039	0.5133	0.6433	0.7527	0.8194

B10	0.5769	0.4904	0.5121	0.5479	0.6698	0.6439
B11	0.6641	0.6454	0.5639	0.7362	0.8620	0.8299
B12	0.6125	0.6373	0.7432	0.6573	0.7597	0.7675

Correlation Matrix

	B7	B8	B9	B10	B11	B12
B1	0.5545	0.5576	0.6275	0.5769	0.6641	0.6125
B2	0.3940	0.5478	0.5039	0.4904	0.6454	0.6373
B3	0.7113	0.5700	0.5133	0.5121	0.5639	0.7432
B4	0.5473	0.6315	0.6433	0.5479	0.7362	0.6573
B5	0.5562	0.7422	0.7527	0.6698	0.8620	0.7597
B6	0.5935	0.7566	0.8194	0.6439	0.8299	0.7675
B7	1.0000	0.4456	0.4743	0.5365	0.5263	0.6260
B8	0.4456	1.0000	0.7050	0.5145	0.6857	0.6814
B9	0.4743	0.7050	1.0000	0.6197	0.6820	0.6872
B10	0.5365	0.5145	0.6197	1.0000	0.6574	0.6070
B11	0.5263	0.6857	0.6820	0.6574	1.0000	0.6755
B12	0.6260	0.6814	0.6872	0.6070	0.6755	1.0000

Principal Component Analysis

Eigenvalues of the Correlation Matrix

	Eigenvalue	Difference	**Proportion**	Cumulative
PRIN1	**8.08679**	7.28834	**0.673899**	0.67390
PRIN2	**0.79845**	0.17498	**0.066537**	0.74044
PRIN3	**0.62347**	0.08457	**0.051956**	0.79239
PRIN4	**0.53890**	0.07508	**0.044908**	0.83730
PRIN5	**0.46382**	0.10027	**0.038652**	0.87595
PRIN6	**0.36355**	0.07684	**0.030296**	0.90625
PRIN7	**0.28671**	0.03239	**0.023892**	0.93014
PRIN8	**0.25432**	0.03191	**0.021193**	0.95133
PRIN9	**0.22241**	0.01026	**0.018534**	0.96987
PRIN10	**0.21215**	0.11387	**0.017679**	0.98755
PRIN11	**0.09828**	0.04712	**0.008190**	0.99574
PRIN12	**0.05116**	.	**0.004264**	1.00000

Principal Component Analysis

Eigenvectors

	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5	PRIN6
B1	**0.270785**	0.075427	0.251488	0.568155	-.478221	-.347533
B2	**0.265839**	-.077662	-.567814	0.514686	0.077476	0.201404

B3	**0.281311**	0.483210	-.296332	-.078013	-.101379	0.155140
B4	**0.287511**	-.046366	-.251064	-.302489	0.452446	-.338290
B5	**0.329734**	-.148804	-.092703	0.023656	0.064893	-.074528
B6	**0.327636**	-.155148	0.002727	-.119552	-.038490	-.076236
B7	**0.246176**	0.678809	0.226753	-.181449	0.026335	-.256899
B8	**0.281689**	-.284272	-.038975	-.352575	-.372834	0.151556
B9	**0.288622**	-.300239	0.320808	-.224355	-.218240	0.067680
B10	**0.262665**	0.013046	0.539828	0.255841	0.519949	0.465070
B11	**0.306859**	-.230304	0.040161	0.099564	0.242367	-.393555
B12	**0.302868**	0.146553	-.077543	-.130094	-.167952	0.473349

Principal Component Analysis

Eigenvectors

	PRIN7	PRIN8	PRIN9	PRIN10	PRIN11	PRIN12
B1	-.027228	0.280463	-.076064	-.262656	-.171483	0.043410
B2	-.078622	0.142914	0.160648	0.481410	0.072369	0.003376
B3	0.001700	-.108229	-.568306	-.229974	0.392519	0.132211
B4	-.194500	0.556665	-.050023	-.219973	-.205022	0.029615
B5	0.030670	-.419831	-.226326	-.063229	-.309457	-.722516
B6	-.126129	-.441563	-.106049	0.169999	-.435233	0.637597
B7	0.088469	-.013145	0.278699	0.471858	-.048903	-.129882
B8	0.655890	0.301861	-.057904	0.164851	-.012040	-.007253
B9	-.606867	0.100911	-.075586	0.255317	0.392559	-.132735
B10	0.174022	0.131235	-.183137	-.000787	-.047102	0.063767
B11	0.277950	-.294618	0.318504	-.198053	0.557573	0.109686
B12	-.156682	-.050908	0.598948	-.459178	-.119642	-.023446

SAS PROGRAM to test for dimensions of the performance data from the 12 questions evaluating performance in Part III of the survey.

```
OPTIONS LS=72 NODATE;
DATA PERF;
INPUT B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12;
CARDS;
2  2  2  4  4  4  3  2  2  3  4  3
7  7  7  7  7  7  7  7  7  7  7  7
6  7  7  7  7  7  7  6  5  7  6  7
1  4  1  4  1  1  1  1  1  1  1  1
7  7  5  7  7  7  7  7  7  7  7  7
6  7  6  7  7  7  5  7  7  7  6  5
7  6  7  6  6  6  7  6  4  6  6  6
6  6  6  7  7  7  6  5  6  6  6  6
6  4  4  6  4  4  4  5  4  6  5  3
6  6  6  7  6  6  6  6  6  6  6  6
7  7  6  7  7  5  6  7  3  7  7  6
6  6  6  6  6  7  6  6  6  6  6  6
7  6  6  7  7  7  7  7  7  7  7  7
3  3  3  5  3  4  4  4  3  4  5  3
5  3  5  6  5  5  5  5  4  4  5  5
6  5  5  7  6  6  6  6  6  6  6  4
6  6  6  7  7  6  6  6  5  7  6  6
6  6  6  6  6  6  4  6  5  5  6  5
6  5  5  5  4  5  6  2  4  5  3  3
5  6  4  3  4  4  4  5  4  4  5  4
6  6  5  7  6  7  6  6  6  6  6  6
3  4  4  7  7  7  5  7  6  6  6  2
6  7  7  7  7  6  6  4  4  5  7  4
7  7  7  7  7  7  7  6  6  7  7  7
6  5  6  6  6  6  6  5  5  6  6  5
6  6  5  6  6  6  5  6  6  6  6  5
7  6  6  7  7  6  5  6  5  5  6  5
6  1  5  2  2  2  4  2  1  3  2  2
7  7  6  7  7  7  7  7  4  1  7  7
3  2  4  5  4  4  4  2  3  3  3  3
6  6  6  7  7  7  7  7  5  7  7  7
7  5  7  7  7  7  7  7  7  6  6  6
5  6  7  7  6  6  7  6  5  6  5  5
7  7  7  7  7  7  6  6  6  6  6  6
7  7  6  7  7  7  6  6  6  6  6  6
7  7  7  7  7  7  6  5  5  6  5  6
5  5  6  6  5  5  4  7  5  2  2  5
3  1  2  3  3  3  7  2  2  1  4  1
3  2  2  4  4  4  3  3  4  3  4  3
7  6  6  7  7  7  7  7  7  7  7  7
7  5  6  7  7  7  7  7  7  7  7  7
6  5  5  7  6  6  7  6  6  7  6  6
7  5  4  7  7  7  3  7  7  7  7  6
```

```
7 6 6 7 7 7 2 7 7 1 7 6
7 6 6 7 7 7 6 6 6 6 7
4 5 5 7 6 6 4 5 6 2 5 4
6 5 7 7 7 7 7 7 7 7 6 6
5 2 6 7 6 6 6 6 6 7 6 6
5 5 1 5 3 2 1 1 2 5 5 1
6 6 7 5 6 6 7 5 5 6 5 6
6 3 6 6 6 6 6 6 4 6 6 5
7 7 7 7 7 7 7 7 4 7 7 7
7 7 6 7 7 7 6 6 4 6 7 6
6 4 5 6 4 5 6 6 5 6 5 5
7 3 6 7 7 7 6 6 6 7 7 6
5 6 5 6 6 6 4 6 4 3 6 1
6 5 3 6 6 6 4 6 6 6 6 6
6 5 6 7 7 7 6 7 7 6 6 6
7 6 5 7 7 7 5 7 7 7 6 6
7 7 3 6 7 6 3 5 6 6 6 5
7 7 6 7 7 7 6 7 6 6 7 6
6 5 6 7 6 6 7 5 6 6 6 6
1 6 6 6 6 6 2 5 2 5 5 6
7 7 7 7 7 7 7 7 7 7 7 7
7 6 5 7 7 7 5 7 4 7 7 3
6 6 7 6 6 6 5 5 6 5 6 6
6 5 3 1 6 6 3 5 5 7 5 4
5 6 6 7 6 6 6 5 4 5 6 5
7 4 3 4 4 6 6 4 4 4 4 4
6 4 6 3 6 4 5 3 3 5 4 4
6 2 2 5 5 5 3 5 4 4 5 2
2 1 1 1 1 1 1 6 1 1 1 1
4 3 4 6 3 2 5 3 2 4 3 3
6 6 6 7 7 7 6 6 6 6 6 6
7 7 7 7 7 6 7 7 4 6 6 6
5 6 5 7 6 6 6 7 5 5 6 6
;
proc princomp data=perf out=result;
var B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12;
run;
```

Appendix H

Performance Data

The answers to the questions in part II of the survey were used to calculated the average accuracy rating and the performance rating. Due to the results of the principle components analysis, the performance rating was determined as an average of the twelve questions in part III section B of the survey.

Performance Data

Participant	A1	A2	A3	A4	A5	A6	A7	A8	Avg A	Avg B	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
0.1	2	2	1	1	1	2	2	1	1.50	2.92	2	2	2	4	4	4	3	2	2	3	4	3
0.2	4	4	2	3	3	3	3	4	3.25	7.00	7	7	7	7	7	7	7	7	7	7	7	7
1	2	3	1	2	2	3	1	1	1.88	6.58	6	7	7	7	7	7	7	6	5	7	6	7
7	1	3	1	1	1	1	1	1	1.25	1.50	1	4	1	4	1	1	1	1	1	1	1	1
12	3	4		3	2	2	2	2	2.57	6.83	7	7	5	7	7	7	7	7	7	7	7	7
13		3		3	3	3	2		2.80	6.42	6	7	6	7	7	7	5	7	7	7	6	5
15	3	4	3	3	4	2	4	2	3.13	6.08	7	6	7	6	6	6	7	6	4	6	6	6
23	3	2	2	4	3	3	3	3	2.88	6.17	6	6	6	7	7	7	6	5	6	6	6	6
29	1	1	2	3	3	3	2	2	2.13	4.58	6	4	4	6	4	4	4	5	4	6	5	3
34	3	4	1	3	3	3	2	2	2.63	6.08	6	6	6	7	6	6	6	6	6	6	6	6
35	3	2	1	3	3	3	3	1	2.38	6.25	7	7	6	7	7	5	6	7	3	7	7	6
36	3	3	3	3	3	3	4	2	3.00	6.08	6	6	6	6	6	7	6	6	6	6	6	6
38	4	3	2	4	2	3	1	1	2.50	6.83	7	6	6	7	7	7	7	7	7	7	7	7
45	1	2	1	1	2	2	2	1	1.50	3.67	3	3	3	5	3	4	4	4	3	4	5	3
51	4	4	3	3	3	2	1	2	2.75	4.75	5	3	5	6	5	5	5	5	4	4	5	5
52	4	3	2	3	3	2	3	4	3.00	5.75	6	5	5	7	6	6	6	6	6	6	6	4
53	3	4	1	1	2	3	1	1	2.00	6.17	6	6	6	7	7	6	6	6	5	7	6	6
56	2	3	1	2	2	2	1	1	1.75	5.58	6	6	6	6	6	6	4	6	5	5	6	5
58	2	1	1		2	1	3	1	1.57	4.42	6	5	5	5	4	5	6	2	4	5	3	3
60	2	3	1	1	1	2	3	1	1.75	4.33	5	6	4	3	4	4	4	5	4	4	5	4
61	4	3	2	2	3	3	2	2	2.63	6.08	6	6	5	7	6	7	6	6	6	6	6	6
62	2	1	1	1	2	2	1	1	1.38	5.33	3	4	4	7	7	7	5	7	6	6	6	2
64	4	2	2	2	3	2	1	1	2.13	5.83	6	7	7	7	7	6	6	4	4	5	7	4
69	4	4	3	4	4	3	3	4	3.63	6.83	7	7	7	7	7	7	7	6	6	7	7	7
70	4	3	2	2	3	3	2	2	2.63	5.67	6	5	6	6	6	6	6	5	5	6	6	5
71	3	2	1	2	2	2	2	2	2.00	5.75	6	6	5	6	6	6	5	6	6	6	6	5
73	2	1	1	3	3	3			2.17	5.92	7	6	6	7	7	6	5	6	5	5	6	5
74*	2	2	1	1	1	1	2	1	1.38	2.67	6	1	5	2	2	2	4	2	1	3	2	2
77*	1	1	1	2	1	1	1	1	1.13	6.17	7	7	6	7	7	7	7	7	4	1	7	7
81	2	3	1	1	1	1	2	2	1.63	3.33	3	2	4	5	4	4	4	2	3	3	3	3
82	1	4	1	1	4	4	3	2	2.50	6.58	6	6	6	7	7	7	7	7	5	7	7	7
83	4	4	2	2	4	3	4	3	3.25	6.58	7	5	7	7	7	7	7	7	7	6	6	6
84	3	4	1	2	2	3	3	2	2.50	5.92	5	6	7	7	6	6	7	6	5	6	5	5
86*	1	3		3	3	3	1	1	2.14	6.50	7	7	7	7	7	7	6	6	6	6	6	6
90	3	4	2	3	4	3	4	2	3.13	6.42	7	7	6	7	7	7	6	6	6	6	6	6
93	3	3	3	3	3	3	3	3	3.00	6.25	7	7	7	7	7	7	6	5	5	6	5	6
101	1	3	2	3		4	3	1	2.43	4.75	5	5	6	6	5	5	4	7	5	2	2	5
103	1	1	1	1	2	3	1	1	1.38	2.67	3	1	2	3	3	3	7	2	2	1	4	1
104	1	1	1	1	1	1	1	1	1.00	3.25	3	2	2	4	4	4	3	3	4	3	4	3
112	4	4	2	4	4	4	3	2	3.38	6.83	7	6	6	7	7	7	7	7	7	7	7	7
114	4			4	4		4	4	4.00	6.75	7	5	6	7	7	7	7	7	7	7	7	7
117	3	4	1	4	2	2	1	1	2.25	6.08	6	5	5	7	6	6	7	6	6	7	6	6
125	4	4	2	3	4	3	4	3	3.38	6.17	7	5	4	7	7	7	3	7	7	7	7	6
130	4	3	1	2	2	2	3	2	2.38	5.83	7	6	6	7	7	7	2	7	7	1	7	6
133	3	4	3	3	3	3	3	3	3.13	6.45	7	6	6	7	7	7	6	6	6	6	7	
140	3	3	3	3	3	2	2	2	2.63	4.92	4	5	5	7	6	6	4	5	6	2	5	4
141	2	4	1	3	2	3			2.50	6.58	6	5	7	7	7	7	7	7	7	7	6	6
146	3	2	2	3	2	2		3	2.43	5.75	5	2	6	7	6	6	6	6	6	7	6	6
149	2	3	3	3	2	2	4	1	2.50	3.00	5	5	1	5	3	2	1	1	2	5	5	1
151	3	4	2	3	3	3	2	2	2.75	5.83	6	6	7	5	6	6	7	5	5	6	5	6
152	3			3	2	3			2.75	5.50	6	3	6	6	6	6	6	6	4	6	6	5
158	3	2		4	4	3			3.20	6.75	7	7	7	7	7	7	7	7	4	7	7	7
159	3	4	4	4			3	4	3.67	6.33	7	7	6	7	7	7	6	6	4	6	7	6
160	2	3	2	2	2	2	2	2	2.13	5.25	6	4	5	6	4	5	6	6	5	6	5	5
164	4	3		3	2	2	3	2	2.71	6.25	7	3	6	7	7	7	6	6	6	7	7	6
170	3	4	1	2	3	3			2.67	4.83	5	6	5	6	6	6	4	6	4	3	6	1
171	4	4	2	4	3	3	4	3	3.38	5.50	6	5	3	6	6	6	4	6	6	6	6	6
174	4	4	2	4	4	3	3	4	3.50	6.33	6	5	6	7	7	7	6	7	7	6	6	6

Blanks indicate that the company does not use that functional module.

Performance Data

Participant	A1	A2	A3	A4	A5	A6	A7	A8	Avg A	Avg B	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
176	4	4	2	2	3	2	4	4	3.13	6.42	7	6	5	7	7	7	5	7	7	7	6	6
177	2	3	2	3	2	2	1	1	2.00	5.58	7	7	3	6	7	6	3	5	6	6	6	5
187	4	3	1	2		4			2.80	6.58	7	7	6	7	7	7	6	7	6	6	7	6
197	3	4	3	3	4	4	2	3	3.25	6.00	6	5	6	7	6	6	7	5	6	6	6	6
207	3	3		1	1	1	1	1	1.57	4.67	1	6	6	6	6	6	2	5	2	5	5	6
215	4	4	1	4	4	4	1	1	2.88	7.00	7	7	7	7	7	7	7	7	7	7	7	7
216	2	3	3	2	3	3	4		2.86	6.00	7	6	5	7	7	7	5	7	4	7	7	3
218	2	2	1	2	2	2	3		2.00	5.83	6	6	7	6	6	6	5	5	6	5	6	6
219	4	4		3	4	4	2	1	3.14	4.67	6	5	3	1	6	6	3	5	5	7	5	4
221	2	3	1	2	3	3	4	4	2.75	5.58	5	6	6	7	6	6	6	5	4	5	6	5
224	3	2			1		2		2.00	4.50	7	4	3	4	4	6	6	4	4	4	4	4
228	3	3	3	3	3			3	3.00	4.42	6	4	6	3	6	4	5	3	3	5	4	4
229	2	1	1	2	2	2	1	2	1.63	4.00	6	2	2	5	5	5	3	5	4	4	5	2
238	1	1			4	4	1	1	2.00	1.50	2	1	1	1	1	1	1	6	1	1	1	1
239	2	3				1			2.00	3.50	4	3	4	6	3	2	5	3	2	4	3	3
240	4	3	2	3	3	3	3	2	2.88	6.25	6	6	6	7	7	7	6	6	6	6	6	6
242	4	3	1	2	4	3	1	1	2.38	6.42	7	7	7	7	7	6	7	7	4	6	6	6
246	4	3	2	4	2	3	2	2	2.75	5.83	5	6	5	7	6	6	6	7	5	5	6	6

Actual answers for B1-6, B8, B9, B11, and B12 were placed in reverse order so that the best performance is indicated by the highest numbers.

1 => 7
2 => 6
3 => 5
4 => 4
5 => 3
6 => 2
7 => 1

Blanks indicate that the company does not use that functional module.

APPENDIX I

Data Used for Hypotheses Tests

Table I.1.

Data Used to Test for Correlation between Accuracy and Performance against the Level of Upper Management Support (Hypothesis 2A)

Accuracy	*Perf.*	*Level*		*Accuracy*	*Perf.*	*Level*		*Accuracy*	*Perf.*	*Level*		*Accuracy*	*Perf.*	*Level*
1.25	1.50	1		1.88	6.58	2		3.25	7.00	3		1.50	2.92	4
2.00	6.17	1		2.38	6.25	2		2.80	6.42	3		2.57	6.83	4
2.13	5.83	1		1.50	3.67	2		3.13	6.08	3		2.50	6.83	4
2.43	4.75	1		1.38	5.33	2		2.88	6.17	3		1.75	4.33	4
1.38	2.67	1		1.63	3.33	2		2.13	4.58	3		2.50	6.58	4
1.38	2.67	1		3.38	6.17	2		2.63	6.08	3		3.25	6.58	4
2.14	6.50	1		2.50	6.58	2		3.00	6.08	3		3.38	6.83	4
				2.50	3.00	2		2.75	4.75	3		4.00	6.75	4
				2.75	5.50	2		3.00	5.75	3		2.25	6.08	4
				3.67	6.33	2		1.75	5.58	3		2.38	5.83	4
				2.67	4.83	2		1.57	4.42	3		3.13	6.45	4
				2.00	5.58	2		2.63	6.08	3		2.63	4.92	4
				3.25	6.00	2		3.63	6.83	3		2.43	5.75	4
				1.57	4.67	2		2.63	5.67	3		3.20	6.75	4
				2.00	4.50	2		2.00	5.75	3		3.13	6.42	4
				1.63	4.00	2		2.17	5.92	3		2.88	7.00	4
				2.75	5.83	2		2.50	5.92	3				
								3.13	6.42	3				
								3.00	6.25	3				
								1.00	3.25	3				
								2.75	5.83	3				
								2.13	5.25	3				
								2.71	6.25	3				
								3.38	5.50	3				
								3.50	6.33	3				
								2.80	6.58	3				
								2.86	6.00	3				
								2.00	5.83	3				
								3.14	4.67	3				
								2.75	5.58	3				
								3.00	4.42	3				
								2.00	1.50	3				
								2.00	3.50	3				
								2.88	6.25	3				
								2.38	6.42	3				
								1.13	6.17	3				

Table I.2.

Data Used to test Accuracy and Performance of Upper Management Initiated Systems against Systems Not Initiated by Upper Management (Hypothesis 2B)

	1-Uppr Mgt Initiated		*2-Not Up Mgt Initiated*	
	Accuracy	***Performance***	***Accuracy***	***Performance***
1	1.75	4.33	2.00	3.50
2	2.00	4.50	2.43	4.75
3	3.14	4.67	3.38	5.50
4	2.00	5.75	2.63	5.67
5	3.13	6.08	2.13	5.83
6	2.63	6.08	1.13	6.17
7	2.88	6.17	2.88	6.25
8	2.38	6.25	3.20	6.75
9	2.71	6.25	3.63	6.83
10	2.80	6.42	2.50	6.83
11	2.38	6.42	2.17	5.92
12	3.13	6.45	2.75	5.83
13	1.88	6.58	3.38	6.17
14	2.57	6.83	3.25	6.00
15	2.00	5.58	1.25	1.50
16	1.50	2.92	1.00	3.25
17	3.00	6.25	2.67	4.83
18	2.00	1.50	2.00	5.83
19	2.50	6.58	3.67	6.33
20	1.57	4.42	3.25	6.58
21	2.50	3.00	1.38	2.67
22	1.50	3.67	1.38	2.67
23	1.63	4.00	1.63	3.33
24	3.00	4.42		
25	2.13	4.58		
26	1.57	4.67		
27	2.75	4.75		
28	2.63	4.92		
29	2.13	5.25		
30	1.38	5.33		
31	2.75	5.50		
32	1.75	5.58		
33	2.75	5.58		
34	3.00	5.75		
35	2.43	5.75		
36	2.75	5.83		
37	2.38	5.83		
38	2.50	5.92		
39	2.86	6.00		
40	2.63	6.08		
41	3.00	6.08		
42	2.25	6.08		
43	2.00	6.17		
44	3.50	6.33		
45	3.13	6.42		
46	3.13	6.42		
47	2.14	6.50		
48	2.50	6.58		
49	2.80	6.58		
50	4.00	6.75		
51	3.38	6.83		
52	3.25	7.00		
53	2.88	7.00		

Table I.3.

Data Used to test Accuracy and Performance against Levels of Upper Management Involvement with Implementation (Hypothesis 2C)

Involvement Level	Accuracy	Performance		Involvement Level	Accuracy	Performance
1	1.25	1.50		3	1.63	3.33
1	1.38	2.67		3	1.57	4.42
1	2.13	5.83		3	3.00	4.42
1	2.75	5.83		3	2.13	4.58
1	2.00	6.17		3	3.14	4.67
1	2.88	6.25		3	2.75	4.75
1	1.88	6.58		3	2.63	4.92
1	2.50	6.58		3	3.38	5.50
2	1.38	2.67		3	1.75	5.58
2	2.50	3.00		3	2.75	5.58
2	1.00	3.25		3	3.00	5.75
2	2.00	3.50		3	2.00	5.75
2	1.50	3.67		3	2.43	5.75
2	1.63	4.00		3	2.75	5.83
2	1.75	4.33		3	2.38	5.83
2	2.00	4.50		3	2.50	5.92
2	1.57	4.67		3	2.86	6.00
2	2.43	4.75		3	3.00	6.08
2	2.67	4.83		3	2.63	6.08
2	2.13	5.25		3	1.13	6.17
2	2.75	5.50		3	2.71	6.25
2	2.00	5.58		3	3.50	6.33
2	2.63	5.67		3	2.80	6.42
2	2.00	5.83		3	3.13	6.42
2	2.17	5.92		3	2.14	6.50
2	3.25	6.00		3	3.20	6.75
2	3.13	6.08		3	3.38	6.83
2	2.88	6.17		3	2.88	7.00
2	2.38	6.25		4	2.00	1.50
2	3.00	6.25		4	1.50	2.92
2	3.67	6.33		4	1.38	5.33
2	2.80	6.58		4	2.63	6.08
2	3.63	6.83		4	2.25	6.08
2	2.50	6.83		4	2.38	6.42
2	3.25	7.00		4	3.13	6.42
2	3.38	6.17		4	3.13	6.45
				4	2.50	6.58
				4	3.25	6.58
				4	4.00	6.75
				4	2.57	6.83

Table I.4.

Data Used to test Accuracy and Performance against Levels of Upper Management Knowledge of Computer Systems (Hypothesis 2D)

Knowledge Level	Accuracy	Perf.		Knowledge Level	Accuracy	Perf.		Knowledge Level	Accuracy	Perf.
1	1.25	1.50		3	2.00	1.50		4	1.50	2.92
1	1.38	2.67		3	1.63	3.33		4	1.57	4.42
1	2.50	3.00		3	2.00	3.50		4	3.00	5.75
1	2.43	4.75		3	1.63	4.00		4	2.75	5.83
1	3.25	6.00		3	1.75	4.33		4	2.25	6.08
1	1.88	6.58		3	2.13	4.58		4	3.38	6.17
1	2.50	6.58		3	1.57	4.67		4	2.80	6.42
2	1.38	2.67		3	3.14	4.67		4	3.13	6.42
2	1.00	3.25		3	2.63	4.92		4	3.13	6.45
2	1.50	3.67		3	2.13	5.25		4	2.80	6.58
2	3.00	4.42		3	1.38	5.33		4	2.50	6.58
2	2.00	4.50		3	3.38	5.50		4	4.00	6.75
2	2.75	4.75		3	1.75	5.58		4	2.57	6.83
2	2.67	4.83		3	2.63	5.67		4	2.50	6.83
2	2.75	5.50		3	2.00	5.75				
2	2.00	5.58		3	2.75	5.83				
2	2.75	5.58		3	2.17	5.92				
2	2.43	5.75		3	2.50	5.92				
2	2.13	5.83		3	2.86	6.00				
2	2.00	5.83		3	3.13	6.08				
2	2.38	5.83		3	2.63	6.08				
2	2.00	6.17		3	3.00	6.08				
2	1.13	6.17		3	2.63	6.08				
2	2.38	6.25		3	2.88	6.17				
2	3.67	6.33		3	3.00	6.25				
2	2.14	6.50		3	2.71	6.25				
2	3.63	6.83		3	2.88	6.25				
2	3.25	7.00		3	3.50	6.33				
				3	2.38	6.42				
				3	3.13	6.42				
				3	3.25	6.58				
				3	3.20	6.75				
				3	3.38	6.83				
				3	2.88	7.00				

Table I.5.

Data Used to Test for Correlation Between the Accuracy and Performance of MRP Systems against the Level to which MRP software is Customized for the Organization (Hypothesis 3)

Accuracy	*Perf.*	*10n*		*Accuracy*	*Perf.*	*10n*		*Accuracy*	*Perf.*	*10n*		*Accuracy*	*Perf.*	*10n*
1.375	2.667	1		1.250	1.500	2		1.375	2.667	3		2.000	1.500	4
2.500	3.000	1		1.625	3.333	2		1.500	2.917	3		1.000	3.250	4
2.625	5.667	1		3.000	4.417	2		2.000	3.500	3		1.625	4.000	4
3.000	5.750	1		2.125	4.583	2		1.500	3.667	3		1.750	4.333	4
2.125	5.833	1		2.667	4.833	2		2.000	4.500	3		1.571	4.417	4
3.125	6.083	1		3.375	5.500	2		3.143	4.667	3		1.571	4.667	4
2.875	6.250	1		1.750	5.583	2		2.750	4.750	3		2.125	5.250	4
2.800	6.417	1		2.750	5.583	2		2.429	4.750	3		2.000	5.833	4
2.375	6.417	1		2.750	5.833	2		2.625	4.917	3		2.857	6.000	4
3.250	6.583	1		2.167	5.917	2		1.375	5.333	3		3.000	6.083	4
2.800	6.583	1		2.250	6.083	2		2.750	5.500	3		1.125	6.167	4
3.375	6.833	1		2.875	6.167	2		2.000	5.583	3		3.000	6.250	4
				2.000	6.167	2		2.000	5.750	3		2.500	6.583	4
				3.375	6.167	2		2.429	5.750	3				
				2.375	6.250	2		2.375	5.833	3				
				3.667	6.333	2		2.750	5.833	3				
				3.125	6.417	2		2.500	5.917	3				
				2.143	6.500	2		3.250	6.000	3				
				1.875	6.583	2		2.625	6.083	3				
				3.200	6.750	2		2.625	6.083	3				
				2.571	6.833	2		2.714	6.250	3				
				2.500	6.833	2		3.500	6.333	3				
				3.625	6.833	2		3.125	6.417	3				
				3.250	7.000	2		3.125	6.455	3				
				2.875	7.000	2		2.500	6.583	3				
								4.000	6.750	3				

Table I.6.

Data Used to Test for Correlation between the Accuracy and Performance of MRP Systems against the Length of Time a Company has Used MRP-type Systems (Hypothesis 4)

Accuracy	*Perf.*	*Initial Year*	*Years Used*		*Accuracy*	*Perf.*	*Initial Year*	*Years Used*
1.375	***2.667***	96	1		***2.375***	***5.833***	86	11
3.000	***6.083***	96	1		***2.125***	***4.583***	85	12
1.125	***6.167***	96	1		***2.625***	***6.083***	85	12
1.500	***3.667***	95	2		***3.625***	***6.833***	85	12
2.125	***5.833***	95	2		***3.375***	***6.833***	85	12
2.857	***6.000***	95	2		***1.500***	***2.917***	84	13
2.000	***4.500***	94	3		***2.000***	***3.500***	84	13
2.800	***6.417***	94	3		***2.000***	***6.167***	84	13
2.571	***6.833***	94	3		***2.375***	***6.250***	84	13
3.125	***6.417***	93	4		***2.000***	***1.500***	82	15
2.750	***5.583***	92	5		***2.500***	***3.000***	82	15
2.000	***5.750***	92	5		***2.750***	***5.833***	82	15
2.625	***6.083***	92	5		***3.125***	***6.455***	82	15
3.500	***6.333***	92	5		***3.250***	***6.583***	82	15
2.500	***6.833***	92	5		***3.000***	***6.250***	81	16
1.250	***1.500***	91	6		***4.000***	***6.750***	81	16
1.571	***4.417***	91	6		***3.143***	***4.667***	80	17
3.000	***4.417***	91	6		***2.625***	***4.917***	80	17
2.875	***7.000***	91	6		***2.125***	***5.250***	80	17
1.571	***4.667***	90	7		***2.500***	***5.917***	80	17
3.375	***5.500***	90	7		***3.250***	***7.000***	80	17
1.750	***5.583***	90	7		***2.167***	***5.917***	79	18
2.875	***6.250***	90	7		***2.500***	***6.583***	79	18
2.429	***4.750***	89	8		***1.625***	***4.000***	78	19
2.667	***4.833***	88	9		***2.750***	***4.750***	78	19
2.714	***6.250***	88	9		***2.750***	***5.833***	78	19
3.667	***6.333***	88	9		***3.375***	***6.167***	78	19
3.200	***6.750***	88	9		***3.000***	***5.750***	77	20
1.375	***5.333***	87	10		***2.500***	***6.583***	77	20
2.000	***5.583***	87	10		***2.143***	***6.500***	74	23
2.429	***5.750***	87	10		***2.625***	***5.667***	72	25
2.000	***5.833***	87	10		***2.250***	***6.083***	72	25
2.375	***6.417***	87	10		***3.250***	***6.000***	71	26
1.875	***6.583***	87	10		***3.125***	***6.083***	64	33
1.750	***4.333***	86	11					

Table I.7.

Data Used to Test for Correlation between the Accuracy and Performance of MRP Systems against Type of Training Provided(Hypothesis 5A)

Type of Training: 1= External Consultants, 2= In-house Experts,
3= Both External Consultants and In-house Experts, 4= None

Accuracy	*Perf.*	*Type of Training*		*Accuracy*	*Perf.*	*Type of Training*		*Accuracy*	*Perf.*	*Type of Training*
2.125	***5.250***	1		***2.500***	***3.000***	2		***1.571***	***4.417***	3
2.000	***3.500***	1		***2.625***	***5.667***	2		***2.500***	***6.583***	3
1.500	***3.667***	1		***2.800***	***6.417***	2		***1.500***	***2.917***	3
2.500	***5.917***	1		***2.375***	***6.417***	2		***1.375***	***5.333***	3
3.250	***6.000***	1		***3.250***	***6.583***	2		***2.625***	***6.083***	3
3.000	***4.417***	1		***2.800***	***6.583***	2		***3.125***	***6.417***	3
3.375	***6.167***	1		***3.375***	***6.833***	2		***1.875***	***6.583***	3
3.200	***6.750***	1		***2.000***	***1.500***	2		***2.571***	***6.833***	3
2.875	***7.000***	1		***1.000***	***3.250***	2		***1.375***	***2.667***	4
				1.625	***4.000***	2		***3.000***	***5.750***	4
				1.571	***4.667***	2		***2.125***	***5.833***	4
				2.000	***5.833***	2		***3.125***	***6.083***	4
				2.857	***6.000***	2		***2.875***	***6.250***	4
				3.000	***6.083***	2		***1.750***	***4.333***	4
				1.125	***6.167***	2		***3.000***	***6.250***	4
				2.000	***4.500***	2		***1.375***	***2.667***	4
				3.143	***4.667***	2		***2.750***	***4.750***	4
				2.429	***4.750***	2		***2.625***	***4.917***	4
				2.429	***5.750***	2		***2.750***	***5.500***	4
				2.625	***6.083***	2		***2.000***	***5.583***	4
				3.500	***6.333***	2		***2.000***	***5.750***	4
				3.125	***6.417***	2		***2.375***	***5.833***	4
				2.500	***6.583***	2		***2.750***	***5.833***	4
				4.000	***6.750***	2		***2.714***	***6.250***	4
				1.625	***3.333***	2		***3.125***	***6.455***	4
				2.667	***4.833***	2		***1.250***	***1.500***	4
				1.750	***5.583***	2		***3.375***	***5.500***	4
				2.750	***5.583***	2		***2.750***	***5.833***	4
				2.167	***5.917***	2		***2.875***	***6.167***	4
				2.250	***6.083***	2		***2.000***	***6.167***	4
				2.375	***6.250***	2		***3.667***	***6.333***	4
				2.500	***6.833***	2		***2.143***	***6.500***	4
				3.625	***6.833***	2		***3.250***	***7.000***	4

Table I.8.

Data Used to Test for Differences in Performance between Companies with a Budget for MRP Training against those that have No Training Budget. (Hypothesis 5B)

Budget for Training			No Budget for Training	
AccyYes	*PerfYes*		*AccyNo*	*PerfNo*
2.000	1.500		1.250	1.500
1.500	2.917		1.375	2.667
1.000	3.250		1.375	2.667
2.000	3.500		2.500	3.000
1.500	3.667		1.625	3.333
1.571	4.417		1.625	4.000
3.000	4.417		1.750	4.333
2.667	4.833		2.000	4.500
2.625	4.917		2.125	4.583
1.375	5.333		1.571	4.667
2.750	5.500		3.143	4.667
3.375	5.500		2.750	4.750
1.750	5.583		2.429	4.750
2.750	5.583		2.125	5.250
2.375	5.833		2.000	5.583
2.750	5.833		2.625	5.667
2.167	5.917		3.000	5.750
2.500	5.917		2.000	5.750
3.250	6.000		2.429	5.750
2.857	6.000		2.125	5.833
2.625	6.083		2.000	5.833
3.375	6.167		2.750	5.833
3.000	6.250		3.125	6.083
2.875	6.250		3.000	6.083
2.800	6.417		2.625	6.083
3.125	6.417		2.250	6.083
3.125	6.417		2.875	6.167
2.375	6.417		2.000	6.167
3.125	6.455		2.375	6.250
3.200	6.750		3.667	6.333
2.500	6.833		3.500	6.333
3.375	6.833		2.143	6.500
2.714	6.250		1.875	6.583
			2.500	6.583
			3.250	6.583
			2.500	6.583
			2.800	6.583
			4.000	6.750
			2.571	6.833
			3.625	6.833
			3.250	7.000
			2.875	7.000

Table I.9.

Data Used to Test for a Relationship between Performance and the Level to which Lack of Training is Considered a Problem (Hypothesis 5C)

Level	Accuracy	Perf.	Level	Accuracy	Perf.	Level	Accuracy	Perf.
0	1.750	4.333	3	2.000	1.500	5	1.250	1.500
0	3.000	5.750	3	1.571	4.417	5	1.375	2.667
0	3.250	6.000	3	2.125	4.583	5	1.000	3.250
0	3.125	6.417	3	2.667	4.833	5	1.625	4.000
0	2.375	6.417	3	3.375	5.500	5	2.000	4.500
0	3.375	6.833	3	1.750	5.583	5	2.429	4.750
0	3.250	7.000	3	2.625	5.667	5	1.375	5.333
1	2.500	3.000	3	2.750	5.833	5	2.000	5.583
1	2.000	3.500	3	2.000	5.833	5	2.875	6.167
1	2.429	5.750	3	2.750	5.833	5	2.500	6.583
1	2.500	5.917	3	2.167	5.917	5	2.875	7.000
1	2.625	6.083	3	2.857	6.000			
1	3.375	6.167	3	3.000	6.083			
1	3.000	6.250	3	3.125	6.455			
1	1.875	6.583	3	3.250	6.583			
1	2.500	6.583	4	1.375	2.667			
1	2.800	6.583	4	1.500	2.917			
1	2.500	6.833	4	1.500	3.667			
1	3.625	6.833	4	3.000	4.417			
2	2.750	5.500	4	1.571	4.667			
2	2.375	5.833	4	3.143	4.667			
2	2.625	6.083	4	2.750	4.750			
2	2.250	6.083	4	2.625	4.917			
2	2.000	6.167	4	2.125	5.250			
2	2.714	6.250	4	2.750	5.583			
2	3.667	6.333	4	2.000	5.750			
2	3.500	6.333	4	2.125	5.833			
2	2.800	6.417	4	3.125	6.083			
2	2.571	6.833	4	2.375	6.250			
			4	2.875	6.250			
			4	3.125	6.417			
			4	2.143	6.500			
			4	4.000	6.750			
			4	3.200	6.750			

Table I.10.

Data Used to Test if Companies with Quality and Productivity Improvement Programs (like TQM) have better MRP System Performance and Accuracy than Companies without such programs (Hypothesis 6A)

TQM-A	TQM-B		TQM-A (conti.)	TQM-B (conti.)		NoTQMA	NoTQMB
3.000	6.250		3.200	6.750		1.250	1.500
4.000	6.750		2.875	7.000		2.500	3.000
2.000	3.500		3.143	4.667		1.625	3.333
2.167	5.917		2.429	4.750		1.500	3.667
3.375	6.833		2.000	5.583		2.000	4.500
2.625	4.917		2.000	5.833		1.571	4.667
3.667	6.333		2.375	6.417		1.375	5.333
1.571	4.417		2.000	1.500		3.375	5.500
2.750	4.750		1.375	2.667		2.125	5.833
2.125	5.250		3.000	4.417		2.375	5.833
1.750	5.583		2.125	4.583		2.750	5.833
2.625	5.667		3.250	6.000		3.125	6.083
3.000	5.750		3.375	6.167		3.000	6.083
2.429	5.750		3.500	6.333		2.375	6.250
2.500	6.583		3.125	6.417		3.125	6.417
2.571	6.833		1.875	6.583		3.125	6.455
1.500	2.917		1.625	4.000		2.500	6.583
2.750	5.583		2.625	6.083		3.625	6.833
2.750	5.833		2.625	6.083			
2.250	6.083		2.000	6.167			
1.125	6.167		2.800	6.417			
2.875	6.250		1.000	3.250			
2.500	6.833		1.750	4.333			
3.250	7.000		2.000	5.750			
1.375	2.667		2.857	6.000			
2.667	4.833		2.875	6.167			
2.750	5.500		3.250	6.583			
2.500	5.917		2.800	6.583			
2.143	6.500						

Table I.11.

Data Used to Test if Companies that have Quality and Productivity Improvement Programs (like TQM) Prior to MRP Implementation have better MRP Performance and Accuracy Than Companies without such programs (Hypothesis 6B)

TQM-A	TQM-B		NoTQMA	NoTQM-B
1.571	4.417		1.625	3.333
2.750	5.583		1.250	1.500
2.500	6.833		2.500	3.000
2.500	5.917		1.500	3.667
3.000	6.250		2.000	4.500
4.000	6.750		1.571	4.667
2.000	3.500		1.375	5.333
3.375	6.833		3.375	5.500
2.500	6.583		2.125	5.833
2.571	6.833		2.375	5.833
			2.750	5.833
			3.125	6.083
			3.000	6.083
			2.375	6.250
			3.125	6.417
			3.125	6.455
			2.500	6.583
			3.625	6.833

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Virginia Polytechnic Institute and State University, Blacksburg, VA
Concentration: Management Systems Engineering

B.S., Industrial Engineering, Dec. 1990, NC State University, Raleigh, NC

Experience

Materials Management Systems Engineering Staff,
Lucent Technologies, Inc., Network Systems, 1600 Osgood St., North Andover, Massachusetts, April 1997 -

Materials Engineer Co-op, Northern Telecom Wireless Network Systems, Raleigh, NC,Summer 1995

- Worked with a team to set-up a quick-response material replenishment system.
- Trained manufacturing associates on Demand Flow Technology (Continuous Flow Manufacturing-JIT concepts.)
- Evaluated material storage equipment, contacted vendors, and provided cost justification for storage equipment design.

Graduate Teaching Assistant, Industrial & Systems Engineering Dept., Virginia Tech, August 1994 - May 1995

- Led Engineering Economy recitation sessions: prepared and reviewed example problems, grade tests and homework sets.

Technical Support Programmer, VIP Computer Systems, Chapel Hill, NC, April 1993 - July 1997

- Provided customer support, identified requirements, modified & tested coded programs.
- Wrote specifications and assisted in the preparation of a manual for a new 4th generation language software product.

Engineer Support Staff, Carolina Power & Light, Nov. 1991-Feb. 1993

- Set up work procedures, determine necessary processes in information routing to engineers, construction managers, and installation crews for a corporate facilities renovations project.
- Assist in project management, materials procurement, schedule planning and in coordinating logistics for moving specialized equipment. Prepared spreadsheets to track contract labor and monitor costs.

Jr. Industrial Engineer, Manpower Technical Services, May-Oct. 1991
for Lucas Cirtek Inc., Pinetops, NC and Revlon Inc., Oxford, NC

- Developed and verified production time standards, revised manufacturing plans for electro-mechanical products. Conducted time studies, verified and updated assembly processes for new production lines.

Co-op Engineer, Southern Bell Co., 1989 (9 months) Raleigh, NC

- Prepared spreadsheets to analyze the economic costs of telecommunications projects. Designed placement of telephone equipment to local businesses and subdivisions.

Honors and Activities

Engineer-In-Training Certification — Institute of Industrial Engineers
Alpha Pi Mu, Industrial Engineering Honor Society — Society of Women Engineers
Biking, Tennis, Handcrafts, Traveling, Hiking, Working with the Youth Group at Church