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COMPUTER INTEGRATED
MANUFACTURING AND AUTOMATED
INVENTORY CONTROL.

by

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DISSERTATION
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requirements for the degree of

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Opsomming.

Hierdie studie gee agtergrond inligting oor tegnologie soos Kunsmatige Intelligensie (AI) en Ekspert Stelsels (ES). Die toepassingsfeer van hierdie tegnologie is die vervaardigings omgewing.

Die aspekte wat geadresseer word, is Rekenaar-Ondersteunde Ontwerp (CAD), Rekenaar-Ondersteunde Vervaardiging (CAM), Vervaardigingshulpbron-beplanning Produksiebeheerstelsels (MRP II) en Rekenaar Geïntegreerde Vervaardiging (CIM).

Die skrywer stel 'n verdere proses of stap voor naamlik Inter Onderneming Inligting Deling (IOIS). Waar CIM ten doel het om interne inligtingsbronne te integreer, het IOIS ten doel om standaard en veilige koppelvlakke te skep, sodat ondernemings en veral verskaffers, vervaardigers en verspreiders sekere vooraf bepaalde inligting kan deel. Die deling van hierdie inligting kan vooruitskattingsfouten verminder en sal help om die verbruiker (kliënt) se behoeftes vinniger te bevredig.

Weens die kardinale rol wat voorraad speel in die vervaardigings proses is dit vir die onderneming van belang om voorraadvlakke so laag as moontlik te hou. 'n Sagteware program is ontwikkel ten einde bestuurders van klein tot middelslag ondernemings te help om inventarise beter te beheer.
Abstract.

This study gives background information on technology like Artificial Intelligence (AI) and Expert Systems (ES). The application realm of this technology is the manufacturing environment.

The strategies that are addressed are, Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Manufacturing Resource Planning (MRP II) and Computer Integrated Manufacturing (CIM).

We propose a further process or step namely: Inter Organizational Information Sharing (IOIS). CIM integrates all internal information sources. IOIS creates standard and secure interfaces so that the organization and other organizations especially suppliers, manufacturers and distributors can share predefined information. The sharing of this information can help make forecasting more accurate and help the organization respond faster to the consumer's ever changing needs.

Due to the fact that inventory plays such an important role in the manufacturing process, a software program was developed to aid the managers in small to medium sized organizations to reduce inventory.
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Chapter 1.

Introduction.

Greater than the tread of mighty armies is an idea whose time has come.

Victor Hugo

1.1. Background and problem definition.

South Africa is facing enormous change on a wide range of fronts: political, economical and social-economical change due to the lifting of sanctions. People to people sanctions are already lifted. Total economical sanctions will be lifted in the near future.

Due to the lifting of economical sanctions South Africa is more accessible to international markets. International markets are more competitive than local markets, due to the protectionism local markets enjoy.

South African business must be able to compete in the dynamic and ever changing market. Due to the isolation uncertainty was much higher for local organizations. Stock piling of products and materials was the only hedge local business had to protect themselves against the ever declining financial rand,
less and less countries willing to support trade with South Africa, and the double digit inflation rate. These are only a few of the macro economical realities a South African organization encounters.

With better trade relations with other countries management is looking at ways to address the problem of run-away stocks. The curbing of run away stocks are not only important for exports but for local manufacturers and distributors as well. One solution is by looking at the implementation of information technology to resolve some of the problems:

Allen [D.1] quotes that on average, 34 percent of the current assets and 90 percent of the working capital of a typical company in the United States are invested in inventory.

If these figures are any indication of the situation in South Africa a company like Barlows with total assets of R18 100 million, according to the Financial Mail Top Companies Survey 26 July 1991, R6 184 million of its assets are locked up in inventory. That is 6 Billion Rand or about 8 percent of the total state (S.A.) spending. Because of factors mentioned previously the situation is probably worse.

Lets say the inventory level can be reduced by 15 percent from R 6 154 million to R5 230,9 million and the reduced inventory is invested at a conservative 15 percent for a year an additional income of R1 062 million can be attained. This additional income can be used to finance special projects to reduce cost even further. The benefits of reducing inventory are plain to see.
The use of information technology in the reduction of inventory are not a once in a lifetime project, but is a process that spans a few disciplines like product design, product manufacturing, product distribution and internal organization configuration.

This study examines ways and means to implement information technology to make a manufacturer more competitive. The preceding section will highlight the main objectives of this study.

1.2. Objectives of study.

The main objectives of this study are:

- The use of Artificial Intelligence and Expert systems in the manufacturing environment currently and in the future with special references to applications in the manufacturing environment.

- To suggest ways to introduce information technology to the manufacturing organization. Discusses relevant terms like Computer-Aided Design and Manufacturing; Manufacturing Resource Planning and Computer Integrated Manufacturing critically. Headings under which each term are discussed are: Definition of term, history, main advantages and disadvantages, how future systems will look like, and well known applications.

- A software application is developed that will help small manufacturers manage inventory better.

- The implementation of Computer Integrated Manufacturing (CIM) is seen as the ultimate information goal. CIM means the complete integration of a company's office, engineering and manufacturing processes. [C.30] We propose
a further goal namely Inter Organization Information Sharing (IOIS). Inter Organization Information Sharing or IOIS can be defined as the exchanging or sharing of information, data and/or information services by vertical chain members.

The implementation of IOIS doesn’t need to wait for the implementation of CIM, it can start as soon as a company has started on the information technology road to success.

1.3. Method of study.

During the completion of this study an attempt was made to integrate the results of literature studies, which examines the use of information technology in the manufacturing environment to reduce the capital locked up in unnecessary inventory.

1.4. Limitations of study.

- This study takes a broad overview of information technology in the manufacturing realm, the discussions is not in depth. The objective of this study was not to discuss or examine a particular area in depth but rather to give a broad overview and identify possible gaps. A major gap was identified: the lack of accurate external information on a timely basis. This gap can be filled by using IOIS - Inter Organization Information Sharing.

- The software program that was written is from an academical perspective and is not practically tested in a real-time production environment.

- The acceptance of the Inter Organizational Information Sharing (IOIS) proposal, as discussed in chapter 12, was not measured. Thus acceptability is uncertain.
1.5. Chapter classification.

The chapter classification are as follows:

Chapter 2: This chapter discusses Artificial Intelligence and Expert Systems on a broad basis and highlights some of the future characteristics we feel is important.

Chapter 3: This chapter looks at different applications of expert systems in the manufacturing environment.

Chapter 4: In this chapter we look at Computer Integrated Manufacturing (CIM), a short history, the main advantages and disadvantages, and the building blocks of CIM.

Chapter 5: This chapter looks at Computer-Aided Design (CAD).

Chapter 6: This chapter looks at Computer-Aided Manufacturing (CAM).

Chapter 7: This chapter looks at the combination of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM).

Chapter 8: This chapter discusses Material Requirements Planning.

Chapter 9: This chapter looks at Just-In Time (JIT) inventory policy.

Chapter 10: This chapter discusses different inventory policies.

Chapter 11: A more in depth discussion on CIM.
Chapter 12: A completely new concept, Inter Organization Information Sharing (IOIS), is discussed.

Chapter 13: The linking of networks using the MAP topology is highlighted.

Chapter 14: The management of all these structural and cultural change.

Chapter 15: This chapter discusses the software program we developed.

Chapter 16: This chapter gives a management overview of some of the more important points discussed in this study.

Chapter 17: Conclusion of the study and future study areas.

-oOo-
Chapter 2.

Introduction to Technology.

"The computer has the potential to be as entertaining as the TV, as educational as the classroom and as easy to operate as the VCR"

David Kay's dream vision of computers

2.1. Introduction.

This chapter defines Artificial Intelligence (AI) and Expert systems (ES), discusses the history of expert systems, and notes the main advantages and disadvantages of expert systems.

Artificial intelligence and expert systems, the two "buzz" words which are increasingly used, are at last finding their way in to the business application sphere. These technologies will reduce the learning curve for a user of information technology.

This chapter gives background information on technologies such as AI and ES. Chapter 3 will look more closely at applications of expert systems in the manufacturing realm.
Expert systems originated out of artificial intelligence research. In order to position expert systems in the information environment artificial intelligence needs to be defined.

2.2. Artificial Intelligence.

2.2.1. Definition of Artificial Intelligence.

In order to define Artificial Intelligence a few well-known definitions of AI as found in the literature will be discussed.

Allen defines Artificial Intelligence (AI) as: "... the ability to learn or understand from experience, and the ability to acquire and retain knowledge. To be considered intelligent one must have the ability to respond quickly and adapt fully to a new situation. Also, the facility of reason must be applied to improve one's level of performance based on one's past experience in solving problems". [D.1]

Rowe et. al. define AI as follows: "the set of computer based systems that enhance the decision maker's ability to arrive at a better solution than could be done without such systems." [A.1]

Fox defines Artificial Intelligence as: "AI studies the principles of intelligence using information processing concepts as its theoretical framework and the computer as its principal tool." [A.5]

Donald Knuth once said: "The difference between art and science is that science is what we can program into a computer. All else is art." [A.29] This is a very broad definition, but it perhaps best sums up Artificial Intelligence.
AI is constantly trying to shift the boundary between Art and Science. It is looking for gaps in the boundary between Art and Science. Wherever these gaps occur and are exploited, the realm of Science is expanded.

Artificial Intelligence has a broad application sphere. Artificial Intelligence has the potential to create a better man–machine interface, so that the machine can communicate more like man by using reasoning, speech, and vision. This application sphere is expanding daily.

AI can be successfully applied right now, provided one is fully aware of its current shortcomings and limitations. In the following section we will discuss a number of advantages of AI.

2.2.2. Advantages of AI.

The advantages of AI are:

\( \text{a) Explicit representation of symbolic structures, behaviour, and reasoning, so that the structures can be examined and reasoned with. [A.15]} \)

\( \text{b) Integration of various types of representation mechanisms.} \)

\( \text{c) Visibility, resulting from the declarative nature of the representation.} \)

\( \text{d) Reasoning, in radically different ways from those attempted by non-AI systems. [A.25]} \)

\( \text{e) Intelligent interaction, based on the representation.} \)
Flexibility/adaptability, resulting from the explicit declarative nature of the representation. [A.15]

It is, however, necessary to be aware of disadvantages related to AI.

2.2.3. Disadvantages of AI.

One of the chief problems in the practical use of AI techniques today is that AI software does not combine well with conventional software. [A.25]

"There's no question as to how the IS community should look at AI — clearly as another technology that should fit within their existing bag of tricks." [A.11]

AI was always seen as a technology separate from other Information Science Technologies. It is, however, unrealistic to see AI as a technology removed from the rest; it must be integrated into existing and future information systems and applications.

The advantages of AI can be gained now, the programmer must identify the aspects he can use from the AI environment and apply them to his specific problem domain.

AI consists of a number of sub fields, which are illustrated in the following section.
2.2.4. Sub fields of AI.

AI consists of sub fields. These fields are computer vision, robotics, speech recognition, expert system, and so on. See Figure 2.1.

Areas in Artificial Intelligence.

Fig. 2.1.

Expert Systems is evidently the most promising area or field. It is also the "cheapest" field and its advantages are enormous. There are wide application possibilities to a wide range of diverse hardware.

Source: [A.3]
Expert systems encourage the interaction of the programmer (in this case the knowledge engineer) with the user or expert. This will lead to better problem definition and will improve the quality and reduce the maintenance costs of the expert system.

2.3. Expert Systems.

The following section critically discusses expert systems.

The application realm of expert systems in the business environment is expanding day by day. The risk is reduced with each new application.

2.3.1. Definition of Expert Systems.

A few of the more widely used definitions of expert systems will be cited, after which the one used by the author will be given.

Fox defines expert systems as follows: "...a computer system which can cope with tasks which require intelligence if carried out by people." [A.5]

Allen states: "An expert system is a computer program that mimics a human expert; using the methods and information acquired and developed by a human expert, an expert system can solve problems, make predictions, suggest possible treatments, and offer advice with a degree of accuracy equal to that of its human counterpart." [D.1]

A formal definition, according to Bowerman et. al., is: "An expert system is a system of software or combined software and hardware capable of competently executing a specific task
usually performed by a human expert. Expert systems are highly specialized computer systems capable of simulating that element of a human specialist's knowledge and reasoning that can be formulated into knowledge chunks characterized by a set of facts and heuristic rules. Heuristic rules are rules of thumb accumulated by a human expert through intensive problem solving in the domain of a particular task, usually over a period of years.” [A.2]

An expert is defined by Schutzer as: “someone who is recognized as being able to solve a particular class of complex, often ill-defined problems especially well and efficiently.” [A.32]

For the purpose of this dissertation we define expert systems as: a computer system that resolves complex and often ill-defined problems in a narrow domain. These problems are usually resolved by a human expert, whose knowledge about a certain subject is gained by education and/or experience.

General knowledge cannot be encompassed in a knowledge base, as the knowledge base would be too big and complex to manage. Thus expert systems are developed for a specific domain or problem area.

In order to establish the current state of expert systems, we have to look at the history of expert systems.

2.3.2. History of expert system development.

A quick insight into the history of expert systems is illustrated graphically in Figure 2.2. For more detailed discussions see the
following references: [A.2], [A.3], [A.23], [A.36], [A.39] & [A.40].

---

**History of expert systems.**

Fig. 2.2.
2.3.3. Driving forces behind the development of expert systems.

There is a diverse field of driving forces behind the development of expert systems. There are forces that pull the technology and those that push it.

Forces behind the development of expert systems.

Demands pulling

- Scarce expertise
- Perishable expertise
- Declining competence
- Need to automate
- Non-von Neumann architectures
- Practical knowledge engineering techniques
- Improved software techniques
- Maturing AI concepts
- Cheap processors and memory

Knowledge system technology

Technology pushes

Source [A.7]

Fig. 2.3.
2.3.4. **Advantages of expert systems:**

There are many advantages in using expert systems, a few of which are listed here.

- Scarce human abilities can be duplicated and distributed over a wide geographical area, where it is impossible for a human expert to share his knowledge. [A.1] This will protect the human expert against life threatening situations and will give him more time to solve more complex and difficult problems.

- Since the cost of employing a human expert is usually enormous, by duplicating the expert's knowledge, fewer human experts are needed. This would reduce labour costs and would increase the profit of the company.

- As most expert systems have an interface to a database, the expert system can be used as a "intelligent" report writer. [A.3] The data used will be more accurate and thus improve the quality of the decisions.

- Expert systems are always available. [A.1] & [A.2] They are never sick, or late, or on leave, and can be at more than one place at a time.

- Human competence is coded and can be used to educate new experts. [A.32] This will ensure that the expert's knowledge will not be lost.

- The fact that the knowledge has to be coded, forces the expert to think about what he is doing and how he is doing it. This will
help him to put his ideas into perspective and will help him to identify inconsistencies.

The learning process is encouraged due to the fact that the young expert can experiment with the system in a risk-free environment and will be able to see how the system reacts in certain circumstances.

By addressing problems that are too overwhelming, boring, or tiring it can assist the expert to complete his job more productively and successfully. [A.32]

The user has easy access to domain-specific knowledge. [A.3] The client's needs are better addressed because the company can improve its service to its clients.

Expert systems have the advantage over conventional programming, because they are not as data intensive. Data intensive applications are susceptible to data errors or the "garbage in garbage out" syndrome.

Expert systems can be implemented in a modular fashion. One domain can be implemented at a time. The different domain specific expert systems can then be integrated into a central system.

The expert system can be used as a norm which will give quick guidelines to the user or non-expert.

Expert systems do, however, have a few limitations.
2.3.5. Disadvantages of expert systems:

To gain the maximum advantage from expert systems, their limitations must be taken into account.

- A computer can handle only a few sensory inputs. [A.7] This limits its potential to acquire new information quickly and accurately. Man uses his sense organs to obtain information about his environment. To simulate an important organ like the eye is very difficult and complex.

- There is a great drive to interact with the user in natural language. [A.2]

- A major limitation of an expert system is the fact that it cannot code general knowledge. [A.1] This causes the computer to reason with constant certainty even though it is uncertain about the conclusion. A human expert's uncertainty gradually increases as his knowledge about a domain decreases. The expert system either knows or does not know.

- An expert system has no self-knowledge, it cannot evaluate itself. [A.3] It cannot see where it fits into the total problem domain. In short it cannot position itself and identify the type of problem it can address.

- An expert system cannot learn, and can only solve problems that have occurred in the past and are coded in the knowledge base.
"Ironically, the more advanced computer technology became, the more scientists realised how little we know about the working of the human brain." [A.31]

The success of the expert system depends on the motivation and commitment of the person to implement the system correctly.

2.3.6. How an expert system should look.

The user expects an expert system to have the following characteristics.

An expert system should be able [A.32]:

- To explain its reasoning process.
- To explain and substantiate its results.
- To guide the user and to catch user misunderstanding and errors.
- To communicate with the user in the language and terms natural to the user.
- To reflect the domain knowledge as deeply and flexibly as possible.
- To treat the problem domain broadly, preferably from several perspectives.

The following section will examine the future of expert systems.
2.3.7. Future of expert systems.

In our opinion future expert systems will have the following characteristics. These characteristics can be defined in the short and long term.

There will be moves to real-time shells and then to real-time on-line parallel shells. The reason being the improvement of parallel processing power and due to the fact that parallel processing is still in its infancy. [A.13] The future of expert systems is like a triangle where previous knowledge and applications are used as the basis for future applications. This is illustrated in the Figure 2.4.

![The future of expert systems.](image)
Short Term.

The tendency is towards more portability, which will be especially relevant for expert systems. Expert systems and expert system shells should be able to run on multiple hardware and software bases. [A.9]

Data transfer between say UNIX and DOS must be supported. There must be standard interfaces to 3rd generation programming languages and databases. The expert systems shells must be object-oriented and must be able to handle real time updates and enquiries.

Long term.

Real time applications that can be implemented on parallel processors. [A.13]

Links to an intelligent environment. The emergence of intelligent operating systems that can make cross applications links. [A.31]

The user will be able to choose from the following ways to communicate with expert systems: Natural language, Graphical Interface or Speech.

They must have links to CASE (Computer Aided Software Engineering) tools or be part of a CASE tool. Shell to Shell links must be supported. [A.25]

There must be easy and effective ways to assist in knowledge acquisition and to make the process more objective. Traditionally the process is very slow and subjective. [A.19]
Support must be developed for multi-tasking. Because multi-tasking is supported, software security must be part of the shell to help the programmer to protect data and other information and software. The shells must be protected against viruses.

They can be used as building blocks for a large system. Different shells can be used in building a total system. Each of these shells will be developed for specific domains, but will have uniform links to link them together.

2.4. Summary.

Managers of successful expert systems projects do not allow themselves to be guided by the technology alone. To these managers, the application is the emphasis, and user needs are paramount. [A.21]

This chapter has discussed AI and ES at the macro level, by looking at the advantages and disadvantages of these technologies. The future of expert systems is looking bright especially in the field of CASE tools and real-time expert systems.

The following chapter will examine applications of expert systems in manufacturing, at the micro level.

-oOo-
Chapter 3.

Applications of Expert Systems.

"Ready, Fire, Aim!"

Motto for technical innovation

3.1. Introduction.

This chapter looks at different applications of expert systems in the manufacturing environment.

The marriage of artificial intelligence and expert systems technology with conventional information processing techniques allows Inference-Based Data Processing to address manufacturing application needs more effectively.

The use of Inference-Based Data Processing offers the information systems of an organization several advantages. [C.40]

The advantages of Inference-Based Data Processing.

- Businesses can rapidly implement complex business applications to support "mission-critical" functions. These functions are, typically, the selling of the product, and the manufacturing of high quality products.

- Simultaneously, Inference-Based Data Processing (IBDP) ensures that these systems remain flexible enough to respond to changing business requirements.
• Traditional MIS development cycles are reduced since the requirements specifications are executed directly.
• The process of building IBDP-based expert systems follows a natural "prototyping" methodology where manufacturing users see results in days, rather than months or years.

Expert systems also change the economics of application development by making new classes of applications feasible and justifiable in terms of costs.

Almost all facets of a manufacturing organisation can benefit from applying expert systems. A few examples of areas where manufacturing has already derived benefits include: Production, Maintenance, Engineering and many more. These areas are illustrated in Table 3.1. Each area has a short description followed by a reference to an application.
### Table 3.1. Examples of expert systems used in manufacturing.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Scheduling and re-scheduling; inventory and production planning and optimized resource allocation. [C.18]</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Equipment fault diagnosis and customer service advisors. [A.15] [C.8]</td>
</tr>
<tr>
<td>Engineering</td>
<td>Intelligent CAD/CAM; part selection and purchasing. [A.36] [A.40]</td>
</tr>
<tr>
<td>Sales</td>
<td>Product configuration and order entry pricing. [A.8] [D.30]</td>
</tr>
<tr>
<td>Finance</td>
<td>Invoice matching and cash application and credit management. [D.5]</td>
</tr>
<tr>
<td>Payroll</td>
<td>Maintenance of payroll. [A.32]</td>
</tr>
<tr>
<td>MIS</td>
<td>Data entry validation and help desk advisor. [A.19]</td>
</tr>
</tbody>
</table>

The following section discusses a few applications that have been developed and are directly used in or relate to the manufacturing environment.

For general information on artificial intelligence (AI) and more specific expert systems (ES) consult chapter 2, Bowerman [A.2] or Giarratano [A.3].
3.2. Applications.

The subsequent discussion centres on applications of expert systems in the manufacturing environment. By looking at different applications the manufacturer can identify if there are areas in his business where expert systems can help him to be more productive or more responsive to market change. The table below summarizes some of these application areas or spheres.

**Table 3.2. Summary of ES applications**

<table>
<thead>
<tr>
<th>Expert System Name</th>
<th>Application sphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALADIN</td>
<td>Alloy design</td>
</tr>
<tr>
<td>TOPAS</td>
<td>Task oriented planning of assembly flow and its optimization.</td>
</tr>
<tr>
<td>CACE III</td>
<td>Man/Machine environment for Computer Aided Control Engineering.</td>
</tr>
<tr>
<td>HOPES</td>
<td>Real-time radar signal processing system.</td>
</tr>
<tr>
<td>PRAGMA</td>
<td>Visual design interface.</td>
</tr>
<tr>
<td>OASES</td>
<td>Intelligent aid to analyze production problems.</td>
</tr>
<tr>
<td>COGSYS</td>
<td>Real-time system for manufacturing.</td>
</tr>
</tbody>
</table>

Each of these application areas are discussed now.
3.2.1. Using an Expert System to monitor an Automatic Stock Control System.

The theory of the control of stock is well understood, and a large number of firms use automatic stock control and ordering techniques as a major part of their inventory control systems. The effectiveness of such automatic stock control systems, however, depends on the correct selection of system parameters for each item in the inventory and on the accurate reporting of information.

It is not unusual for errors to be made in both the selection of parameters and the entry of data, but failures in either can cause severe problems in stock control. A failure in one or more of these can lead to systematic errors in stock ordering which will ultimately be manifested in periods of overstocking or persistent stockouts. According to Greene [D.18] accuracy of 95 percent or higher is required for the input of data in order for the system as a whole to be unaffected by the inaccurate data.

It is generally difficult for a human stock controller to discover errors quickly because of the large number of items that are usually found in a company's inventory.

One possible response to this problem is to use a computer program to search the stock control files for items which exhibit abnormal behaviour. Such a program needs to recognize irregular behaviour, diagnose its cause, if possible, and report abnormal items to a human controller.
Thorpe et al. [D.30] suggest the use of an expert system to identify these abnormal items and make recommendations regarding to the possible causes of these abnormalities.

The expert system was used in a controlled and simulated stock control environment. This was done to allow the behaviour of the stock control system to be precisely controlled during investigations and thus to provide opportunities for the performance of the expert system to be monitored. This is not possible for real-life data or on-line systems.

The simulation can produce data for several related stock items at once and can insert abnormal patterns into the behaviour of one or more of these items.

At present a list of 16 primary abnormalities has been provided.

These primary abnormalities are:

p0) No abnormal behaviour.

p1) Unexpected change in sales level caused by unreported price reduction.

p2) Unexpected change in sales level caused by unreported price increase.

p3) Temporary increase in sales due to unreported change in sales conditions.

p4) Temporary decrease in sales due to unreported change in sales conditions.
Applications of ES

Chapter 3

p5) Lead time stored in stock database is too short.
p6) Lead time stored in stock database is too long.
p7) Failure to log deliveries.
p8) Deliveries logged without receipt of stock.
p9) Consistently low counting from a human operator.
p10) Consistently high counting from a human operator.
p11) Sales made on incorrect item codes, resulting in a low estimate of sales.
p12) Sales made on incorrect item codes, resulting in a high estimate of sales.
p13) Failure to report stock transfer in.
p14) Failure to report stock transfer out.
p15) The supplier is subject to occasional stockouts.
p16) Incorrect forecasting.

Each of these abnormalities can give rise to a variety of symptoms also known as secondary abnormalities.

The expert system derives its data values from a set of signals intended to determine whether there was a secondary abnormality in the stock system.

These secondary abnormalities are:
s1) Sales mean
s2) Sales standard deviation
s3) Demand mean.

s4) Service level.
s5) Delivery mean.

s6) Order level.
s7) Goods on order.

s8) Stock on hand.

In conclusion, the use of elementary AI techniques can correctly diagnose some abnormalities in the behaviour of a stock control system.

3.2.2. A CAD/CAPP expert system shell.

The Computer-Aided Design/Computer-Aided Process Planning (CAD/CAPP) expert system shell described here consists of an executive level consisting of an extended PROLOG interpreter and several design knowledge based levels, maintaining a design method named Recursive Decomposition Method (RDM). [8.5] A conceptual modelling-based knowledge representation scheme and RDM-oriented built-in solving mechanisms are described. This high level programming environment is intended to be used for the implementation of more flexible CAD/CAPP systems possessing some problem-solving capabilities.
This shell is intended to overcome, to some extent, the most important shortcomings of the traditional CAD/CAPP systems in machine building: insufficient universality and portability, lack of tools for non-numeric problem-solving and decision making processes maintenance.

Some of the important PROLOG extensions implemented at the executive level are the following:

- A control mechanism for external programme modules execution, together with a structured language to develop structured programme systems.
- Nonprocedural 2D graphics facilities.
- Flexible user interface design and management facilities.
- Some deductive data base functions.
- Nonprocedural string operations.

The most significant feature of the above-mentioned extensions is that they are realized in a declarative and recursive PROLOG style.

3.2.3. ALADIN.

ALADIN is a knowledge-based system to aid aluminum alloy design for aerospace applications. Alloy design is a decision process in which basic composition and thermal- and mechanical-process steps, are selected to produce an alloy displaying a set of desired characteristics. [A.40]

ALADIN's goal is to provide a decision support environment in which expert alloy designers can efficiently explore alternative compositions.
ALADIN runs on a Symbolics LISP machine, under Genera 7.1, within Knowledge Craft 3.1. environment. The current ALADIN system has approximately 2400 schemata, 250 Knowledge Craft OPS rules and 200 Lisp functions.

This research has:

• Provided a representation in which multiple partial models can be represented declaratively.
• Formulated an architecture in which incomplete and inconsistent models can be integrated into the design process.
• Satisfied multiple interactive goals by determining least-commitment constraints.
• Developed a framework and applied a set of techniques that permit the effective coupling of symbolic and numerical (qualitative and quantitative) reasoning.
• Found ways to reason qualitatively with constraints that are expressed quantitatively.
• Created an interactive environment where experts can share control of the design process with the system.

ALADIN's overall goal, as an industrial application of AI techniques, has been to make the alloy design process more productive. ALADIN has achieved significant productivity improvements and speeded up the discovery of better alloys by:

(1) making the generation of alloying experiments more systematic;

(2) aiding the evaluation of proposed experiments; and
(3) enabling individual designers to supplement their own specialized expertise with the help of the programme, which is a pool of expertise from various sources.

3.2.4. TOPAS.

TOPAS is an expert system for the task-oriented planning of the assembly flow and its optimization. [C.18]

The assembly planning for real production environments has to fulfill the following requirements:

a) Planning of the assembly flow.

b) Optimization of the assembly flow.

c) Planning of the assembly system layout.

TOPAS delivers solutions for points a) and b).

Planning of the assembly flow can be refined as:

- Generation of the product hierarchy.

- Specification of the operations and definition of all connected external operations.

- Specification of the assembly sequence.

TOPAS comprises a planner and a critic. The planner generates hierarchical assembly graphs and all possible assembly sequences, which are evaluated by AND/OR-graphs. The critic then generates an optimal assembly sequence.
Goals are defined by restrictions and are expressed by rules. The process of goal interaction is considered as a constraint satisfaction technique in order to produce the optimized sequences.

The system is implemented in Common LISP on Symbolic machine (3670) and is supported by KEE and a CAD-system. The total number of rules is about 250.

3.2.5. CACE III.

CACE III is a rule-based expert system for a man/machine environment for Computer-Aided Control Engineering (CACE). [C.8]

Control Engineering activities are:

a) Modelling the plant to be controlled.

b) Determining the characteristics of the plant model.

c) Modifying the configuration to make the plant easier to control.

d) Formulating the elements of the design problem.

e) Checking to see that the design problem is well posed. Determining whether the specifications are realistic in light of the plant model and design constraints.

f) Executing appropriate Design Procedures.

g) Performing design trade-offs, if necessary.
h) Validating the design.

i) Providing complete documentation of the final design.

j) Implementing the final design.

Problems with current CACE software:

- Most CACE packages are specialized to one aspect of the overall design process.
- The problem-solving environment provided by current packages is not very good.
- Most packages provide little or no guidance.
- Most packages provide little or no documentation of the design process.
- Most packages provide little support in validating and implementing the final design.

CACE III governs interactions among the design engineer, plant models, and the model and constraint components of the problem frame. This rule base provides support in model development and supplies the facts required to characterize the plant model and design constraints.

3.2.6. HOPES.

Real-Time problem solving has always been considered to be one of the most difficult problem areas. Traditional expert systems face great difficulties in meeting the requirements of real-time applications. The usefulness and correctness of real-time systems rely not only on the logical result, but also on the time at which the result is produced. In most cases the system
must be able to complete a task in a strictly limited time period.

There are certain problems in designing AI systems for continuous real-time operation that are distinct from aspects common to all knowledge-based programs.

Problems unique to Real-time continuous AI systems:

There are certain problems unique to real-time expert systems. These are discussed here under the following headings: dynamics, time limitations, decisions and uncertainty.

• Dynamics.

The most obvious aspect about real-time environments is their dynamics. The changing state of the world needs consideration from two aspects: how state can be recorded inside the system and whether the actions the system wants to take are state-dependent.

Because we are working with real-time systems, information must consistently be updated. New data is arriving all the time and may support or contradict previous reports. The effects of this have to be propagated through any inferences or hypotheses made on the basis of that data.

The changing state of the world has two implications for a system's plans. First, the sequence of actions in a plan are state-dependent. The system must be able to ensure that a certain state has occurred and must watch for effects of action in order to move to the next step in the plan. Each element of a plan, therefore, has implicit expectations about future
states that the system needs to understand and be able to compare with its state description.

Secondly, plans need to be sufficiently robust. Since the world is changing while a plan is being developed, that plan could be out of date before it is complete. There is no point in simply discarding it and starting again, it must be quickly adapted to the new conditions.

If the plan is discarded and a new plan is developed, it is again susceptible to changes in the world. If these changes do occur, the plan is again outdated. This causes a closed loop which is very difficult to escape, as the system keeps on planning and never produces a result.

• Time limitations.

In a real-time system a response is required within a certain time span. If the response is delayed it might as well not respond. The response is void if it is not reached within the allotted time.

• Critical decisions.

Related to the problem of short response times is the fact that, a system can be making critical judgments, and the time it takes to make them can have significant safety implications. The expert system must be able to distinguish between critical and non-critical problems. The system must be able to see which problems must be solved first or are the most important.
• Uncertainty.

The system must be able to function even though some of the sensors or inputs fail. It must be able to draw conclusions from different inputs even though they are not all known.

Why HOPES?

Hierarchically Organized Parallel Expert System (HOPES) is a real-time radar signal processing and interpretation system. Unlike other traditional expert systems, the HOPES system consists of a few knowledge sources that are hierarchically organized and capable of concurrent execution. [A.23]

The advantages of the HOPES system are as follows:

a) Different kinds of knowledge are arranged in different knowledge sources.

b) Each knowledge source is capable of running concurrently with other knowledge sources. Thus the time needed to complete a task is reduced.

c) Instead of using a single blackboard, a multi-blackboard architecture is proposed in HOPES. This architecture distributes the information used over several blackboards, thus reducing information complexity and simplifying the management of each blackboard. This makes the system more efficient.
d) Results have shown that the HOPES system can offer substantial speed-up for suitable real-time applications.

e) The HOPES system provides a general model of real-time expert systems.

3.2.7. PRAGMA.

PRAGMA is a visual design interface which participates actively in the knowledge acquisition process. [A.19] PRAGMA monitors the design process and makes proposals on the basis of an underlying knowledge base, the current state of the procedure on screen, and the performed user actions. The acquired procedural knowledge can then serve as a knowledge base for an interactive planning system.

In PRAGMA, the acquisition process is organized in the form of a cycle incorporating two basic features:

- **Visual design**: Is a visual interface facilitates in the capturing of procedural knowledge. It also uses an easy to understand graphical language to express and manipulate procedures.

- **Active system participation**: The system actively supports the user in capturing and fixating new knowledge by asking questions and making suggestions.

These two features are realized in interleaved phases. During the design of a procedure via an interactive graphical component, the system analyzes the current procedure, poses questions concerning its structure, and clarifies what kind of new knowledge is to be inserted into the knowledge base.
PRAGMA is implemented on a Symbolics LISP machine using Lisp with Flavors and PROLOG. The knowledge base is realized in PROLOG, so the acquisition of new knowledge corresponds to the assertion of new PROLOG facts. The graphical design interface is implemented in Lisp and integrated into the main features of the planning system VIPS.

3.2.8. OASES.

OASES (Operations AnalySis Expert System) [A.8], is an expert system designed to function as an intelligent assistant and to aid management in analyzing problems in production processes such as fibreglass manufacturing.

The system uses a partitioned rule base representation for the domain knowledge base and a combination of forward and backward inference mechanisms to interact with users.

3.2.9. COGSYS.

COGSYS (COGnitive SYStem) is an expert system designed for real-time applications. [A.13] The real-time application it is designed for has certain characteristics.

Characteristics of real-time applications COGSYS was designed for:

- The problem parameters are time-varying.
- The situations involved are continuous, or at least extend over a significant time span.
- Response is required within a limited time.
Priorities of activities are subject to continual change.

Interfacing to external equipment and other systems is essential.

COGSYS is being developed by a collaborative club of over 30 major companies. COGSYS is intended for operation in industrial environments, and uses standard commercial hardware for its implementation.

The system is produced to a specification which is subject at all stages to approval by club membership.

3.3. Future Applications.

Recent observers of the industrial applications of information systems have suggested that the way in which these systems are used is changing. [A.9], [C.2] & [C.3]

Some companies are using these systems not only to do mandated data processing and to provide management information, but also to improve the competitive positions of their companies relative to other companies in their industries.

There are two ways in which firms have used information systems to enjoy a competitive advantage over their rivals.

The first approach is to use information systems to reduce costs, which results in pricing and profit margin advantages. For example, an inventory control system is used to reduce inventory costs.

The second approach is to use information systems to assist in product or service differentiation. This may be achieved by
improving the quality of the product or service or by offering unique product or service features.

Problems that should be addressed in the future:

The first is the cost of developing a useful expert system. [A.9] This can be quite high, even though it can hold great advantages relative to competitors, because it would reduce time and costs.

Because the commercial development of expert systems is still in its infancy, it is difficult to estimate accurately the risk, duration, cost and benefits of a new expert system development effort. As the industry matures, factors can be calculated more accurately. The companies currently applying expert system technology are the innovators. [A.9]

There is also a definition problem: since expert systems are continually being improved, an expert system may never be complete. Consistent and attainable objectives must be set to monitor the progress of the expert system being developed.

The second problem concerns personnel. [A.9] It is difficult to find knowledge engineers who are competent in expert system technology and who also communicate well with domain experts. This problem can be addressed by using an intermediary who encodes domain knowledge and makes it available to the expert system specialist. Another approach is rapid prototyping.

The problem with personnel is not only the lack of technology specialists, but also the lack of domain experts. How does a
person become a domain expert? A domain expert is a relative concept, it reminds us of the saying in the land of the blind the one eyed is king.

The third problem is misleading information. [A.9] Because the domain expert's knowledge is interpreted by somebody else, there is a grave risk of mis-interpretation. The problem can occur for two reasons: the domain expert cannot communicate his knowledge effectively either because of a lack of communication skills or because he himself does not know how he is doing it. The other side of the problem is: the knowledge engineer misinterprets the messages either because of incorrect knowledge gaining or coding techniques.

3.4. Summary.

This chapter has examined different applications of expert system technology in the manufacturing environment. These applications are implemented by the innovators in the manufacturing arena. These companies are not only in the forefront of technology but are well-structured and geared for market leadership.

The following chapter will examine Computer Integrated Manufacturing (CIM), and whether it is just another new 'buzz' word?
CHAPTER 4.

COMPUTER INTEGRATED MANUFACTURING.

"Would you tell me, please, which way I ought to go from here?"
"That depends a good deal on where you want to get to," said the Cat.

Lewis Carroll, Alice in Wonderland

This chapter examines definitions of Computer integrated manufacturing (CIM), a short history on CIM, the main advantages and disadvantages of CIM, and the building blocks of CIM.

4.1. INTRODUCTION.

Computer integrated manufacturing is one of the fastest growing fields today. The reason is that it uses current and well-proven technologies to help the management of a company to transfer knowledge from one end of the company to the other.
Today's firm has islands of automation, such as Manufacturing Resource Planning (MRP II), office automation, computerized market forecasting and its general ledger system. Huge manual efforts and paper work systems keep the islands from sinking. "CIM digitally links these islands, providing fast, accurate, consistent, on-line data. CIM thereby cuts costs, raises quality, reduces response times and improves white collar productivity." [C.14]

There are many definitions of CIM. Two schools of thought exist: one states that CIM is the complete integration of all the company's information resources. This is sometimes referred to as Computer Integrated Management [C.23]. The definition that is more widely used and accepted is that CIM is the integration of all the information resources needed in the manufacturing of a product or products. [C.10], [C.12], [C.14], [C.30] & [D.18]

"True CIM' means the complete integration of a company’s office, engineering and manufacturing"[C.10]. It will influence the work flow, people, and the culture of the company. The problem, however, is that people are always in a hurry, management wants to see the whole problem solved today. [C.12] These aspects cannot be addressed overnight, but must be changed over a period of time. CIM is a long-term strategy and not a short term project.

CIM uses current technology in new ways. What is new is the way which technology is integrated to solve long-term problems. Integrations of computer components, both hardware
and software, are very difficult due to the fact that there are very few existing standards.

Promises made by Computer aided manufacturing, design and office automation, now have the opportunity to be realized. CIM is an evolution and not a revolution. [C.10] CIM is a management philosophy. [C.23] There is nothing revolutionary to be found in CIM. What is different is that we now can put it all together, as a coherent system. CIM is the umbrella under which all the parts function.

These parts include Computer aided design and manufacturing as well as the assisting information sources and systems.

Because CIM is an emerging field, [C.23] only a few guidelines can be given. These guidelines can help develop standards that will make the process towards a total integrated computer environment much simpler.

The key to success is the effective integration of current technologies. CIM is a evolution, and to build a CIM plant from the very beginning frequently leads to disappointment and disillusionment.

CIM is a business which re-focuses existing and new computerized applications, thereby sharing the combined assets of information networks. [C.14]

The problem confronting CIM managers is to decide which functions are to be performed by whom or what is to do what, and how this should be done. [C.23] This cannot be achieved
overnight; it is a transformation. Management has to know where they are going and which steps to follow.

Along the way there must be intermediate objectives. These objectives must be realistic in order to be achieved. The end result of this process is the complete integration of all the company's computers and stored data, combining all information and working from a common database.

4.2. Goals of computer integrated manufacturing.

CIM is an idea whose time has come. To implement a CIM system we have to take many technologies and blend them together so that the whole is better than the sum of the parts. [C.23]

CIM automates the flow of information through the factory, reducing many costs. These costs are typically direct and indirect labour, and overhead costs. [C.14] This will reduce the break-even point of the factory and will lower the required volume necessary to generate a profit.

Its objective is to achieve greater effectiveness within the entire business, across the whole cycle of product design, manufacturing and marketing.

Islands of automation are: Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing, Office Automation and computerized market forecasting, to name a few. Because islands of automation do exist, huge manual efforts and paperwork systems keep these islands together and stop them from sinking. [C.14]
This leads to more work instead of less, and the effectiveness of the islands as a whole is negatively influenced. CIM digitally links these islands. This gives the user (management) fast, accurate, consistent, on-line data. CIM thereby cuts costs, raises quality, reduces response times and improves white collar productivity (like management).

Thus CIM is a business strategy which re-focuses existing and new computerized applications and technologies.

The driving force behind CIM has always been there, but only now are we able to deliver the results. CIM is able to reduce work in process; if the work in process (WIP) is reduced, this will lead to less inventory.

4.3. Short history of Computer integrated manufacturing.

As with so many aspects of CIM, trying to define the development of the subject means having to consider several different areas simultaneously. The evolution of CIM begins with the evolution of the areas which comprise the elements of CIM.

In 1962 Pat Hanratty moved to General Motors and became involved in the DAC project which was started in 1959 by General Motors and is probably the first industrial use of CAD. He is sometimes called 'the father of CAD/CAM'. [C.26]

By 1965 several CAD projects were well underway, including Design Augmented by Computer (DAC). Bell, Lockheed and McDonnell also had projects underway. [B.7]
During 1968 the first commercial graphics-based CAD system was jointly installed by IBM and Calma. [B.7] In this year there was a major conference on advanced manufacturing principles between US military and industrial organisations.

During 1969 Unix was developed by Ken Thompson who then produced a language called 'B'. This was later rewritten and called 'C'. [C.26] Unix is virtually an industry standard in the engineering and manufacturing worlds, due to the fact that UNIX is so portable. In the same year the term CIM — Computer Integrated Manufacturing — was first used by Joseph Harrington.

IBM undertook the development of an overall concept for a production and inventory control system and published the results in the early 1970's. This was called the Communications Oriented Production Information and Control System and Involved Software (COPICS). [C.37]

In the early 1970's the American Production and Inventory Control Society (APICS) developed guidelines for resource planning, which is now called Manufacturing Resource Planning (MRP II). [C.36]

In 1970 the ISO started working on a set of overall standards for hardware and software communication. [C.11]

In 1973 General Motors had a major success with their Vehicle Structural Analysis Programme (VSAP). General Motors now started playing a major role in advanced manufacturing.
In 1975 the Integrated Computer-aided Manufacturing (ICAM) project was initiated at the Wright-Patterson Air Force base Ohio. [C.26]

The Open Systems Interconnection (OSI) seven-layer model was published by ISO in 1978. [C.43]

In 1980 the first International Graphics Exchange Standards (IGES) was adopted by American National Standards Institute (ANSI). [B.7]

In 1981 a ten year project on Flexible Manufacturing System in Germany was completed. [C.19]

By 1982 the main structure of the ICAM definition model was completed. General Motors defined the Manufacturing Automation Protocol (MAP) as its standard for factory communications and committed itself to purchasing only MAP-compatible products. [D.7]

In 1983 solid modelers started to become commercially usable in CAD/CAM. [B.7]


In 1985 General Motors installed its first MAP pilot project at its plant in Hamtrack, MI. MAP versions 2.0 and 2.1 were released. [C.11] Fiat produced engines at its Fully Integrated Robotised Engine (FIRE) plant in Italy.
In 1987 Esprit I ended and Eprit II was started in 1988. This was a five-year program, whose primary projects were: Very Large-Scale Integration (VLSI), Vision, Distributed intelligence, Robotics, Sensing, Knowledge-based Systems, and Distributed systems. [C.5]

In Figure 4.1, the history of Computer Integrated Manufacturing is summarized.

**History of CIM.**

- OSI by ISO
- Term CIM first used
- Pilot project of MAP
- SOLID
- VSAP
- COPICS
- Release MAP 2.0 & 2.1
- Solid modelling
- First CAD conference
- UNIX developed
- ICAM
- MAP 1.0
- IGES

**Fig. 4.1.**
As can be seen, "CIM is still in its infancy". [C.27] The concept was in fact only first coined in 1969, and there is still a great deal of research to be conducted to make CIM truly accessible to industry.

Some of the major advantages of CIM will now be discussed.


- Computer integrated manufacturing has a positive influence on an organization from the quality of the product right through to the creation of an environment conducive to innovation and change.

- Office and factory productivity increase. [C.21] & [C.30] Tedious and monotonous jobs are the easiest to automate, which leads to higher work satisfaction for workers and stimulates them to perform better.

- The automation of the factory creates safer working conditions for the worker. Since there is less physical participation by the worker in the production process, there is less risk of personal injury.

- CIM projects usually centre around labour costs, but labour accounts for only 10 percent of manufacturing costs. Waste reduction, energy savings, and reduced lead time which account for 35 percent of costs are also reduced by the introduction of CIM. [C.37]

- Engineering and design costs drop. [C.14] The automation of the design process reduces the time it will take to produce new
and innovative designs. This will reduce development costs and time. Because development of products is much faster there can be a closer correlation between the consumer’s (user) needs and wants, and that which the company provide.

- Owing to the culture of innovations and change, as created by management, employee morale is higher. The environment is more conducive to innovations and free thinking. The company must set simple yet effective guidelines that can be followed by all, without being too autocratic.

- Product quality is better and the unit price of the product is lower. [C.10] It is estimated that the cost to manufacture a product by conventional general-purpose machine tools requiring a human operator may be 100 times the cost of manufacturing the same product by using automated mass-production techniques. [C.30]

- CIM can improve capital resource productivity [C.10], as it makes better use of capital resources, by helping the manufacturer to use fewer machines, lower inventory and less space to achieve greater output at lower cost.

- CIM offers greater volumes through greater variety, allowing one to spread one’s major investment in CIM over many different products, with the total number of units creating economy of scale for profitability.

- CIM offers manufacturers a rapid response to the market place. The flexibility of CIM gives one the ability to be first
into the marketplace, and to gain a significant market share before competitors can catch up.

On the macro scale, the growth of the automation industry will in itself provide employment opportunities. Growth in the computer industry and its supporting industries like systems engineering and software design, creates jobs and generates economic growth.

In order to maximize the advantages of CIM, the disadvantages of CIM must be examined.

4.5. Disadvantages of computer integrated manufacturing.

The main problem with CIM is that it demands change from old and well-known forms to a new look at the organization, its structure, culture and products. This is a problem since humans are reluctant to change. Management of technological change is discussed in Chapter 14.

"The irrational pattern of human behavior repeats itself again and again, individually and collectively. Even when our old forms are failing miserably, even when they cannot handle the problems of the day, they are fiercely defended; those who challenge them are derided." [C.10]

Top managers are either very successful and see little need to tinker with policies that worked in the past, or are too cost-conscious to justify the investment required for CIM. In short, top managers are happy not to "rock the boat!!". [C.21]
Another major reason why CIM is not implemented properly is the company is fighting merely to survive, and does not have time to adapt to the new technology. This is caused by poor management in the past. [C.29]

Common data structures, especially between CAD systems and material requirements planning (MRP) systems are not available. [C.33]

Common 'human interfaces' have not yet been developed for CIM components. Even within CIM components, there is a broad variety of dialogues offered by different vendors. [C.33] This confuses the user and muddles the choice of CIM components.

Automation will result in the replacement of humans by machines. The question here is whether the workers' job will be downgraded or upgraded. [F.7] Automation tends to transfer the skill required to perform the job from the human to the machine. In so doing, it reduces the need for skilled labour. The manual work level after automation requires a lower skill level and tends to consist of rather menial tasks.

On the other hand, the routine monotonous tasks are the easiest to automate, and are the first jobs to be automated. Fewer workers are thus needed in these jobs, and there are fewer frustrated workers. Tasks that require judgment and skill are more difficult to automate. The net result is that the overall level of manufacturing labour will upgrade. [C.30] What must be emphasised here is that management must be aware of the fact that the job descriptions of workers will and
should change. The main criterion for success here is the way in which management addresses the problem. If management can create a culture of change without making personnel fear for their jobs, management will have succeeded.

This could possibly lead to the advantages of automation being negated by worker response. The introduction of automation will reduce the need for human labour. This should be especially true in the manufacturing arena. Labour uncertainty will, however, reduce productivity, morale of the work force and reduce acceptance of change. Management has a major role to play here, they must emphasize the concept of quality workers, and that there is thus a role to be played by the productive and hardworking worker in the company after the introduction of automation.

The implementation of flexible manufacturing systems reduces the number of employees by a factor of 4 to 5. [B.8] Although the physical number of workers might drop, the expenditure of the company might in fact rise. This is due to the fact that higher skilled workers are required to repair the technologically more advanced machines, or more will be spent on external contractors to repair these machines.

A forecast for the British manufacturing industry (Figure 4.2.) shows that there is a drastic cut in employment for all occupations, except for a stagnation in the number of managers and a huge growth in the number of technicians. The share of technicians will reach 40% in 1995 and the share of semi- or unskilled workers will drop from 41% to 10%. This will occur partly because of technological changes in the industry. [B.8]
Estimated structural change in employment in the UK Manufacturing Industry.

<table>
<thead>
<tr>
<th>Structure in %</th>
<th>1980</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managers</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Technicians</td>
<td>6</td>
<td>40</td>
</tr>
<tr>
<td>Clerical &amp; administrative staff</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Craftsmen</td>
<td>32</td>
<td>15</td>
</tr>
<tr>
<td>Semi- or unskilled workers</td>
<td>41</td>
<td>10</td>
</tr>
</tbody>
</table>

Source [B.8]

Fig. 4.2.

The main problems generated by CIM are the drastic changes in the structure of demands on the work force. Because this is of such major importance the "management of change" will be discussed in chapter 14.


CIM means computer integrated manufacturing. The goal is to tie all the various computers, and other programmable devices
found in the factory into one integrated network wherever it is operationally advantageous and profitable to do so. [C.23]

The emphasis is on the integration of automated islands; CIM is thus more than technological, it is a management philosophy. The reason why CIM is emerging is because we are entering the new and very competitive world market. Another reason is that CIM gives the manufacturer what he always wanted and needed; a tool that has total control of his inventory and manufacturing process.

In light of CIM's potential to alter structures throughout an organization, as well as the large hardware component of its cost, it makes sense to apply CIM in measured doses today, preparing the site for more extensive installations later. [C.37]

There is little point in implementing CIM unless it is preceded by sound management methods, and quality standards are maintained. Good control procedures are essential for success.

A company must first change the way people think about automation before automation starts. "CIM is a journey it's a means to an end not an end in itself. It's not something you do in a year." [C.12]

CIM is a process of discovery; the organization must evaluate itself and see how CIM can help it to reach its objectives. The organization must identify its needs and apply technology to satisfy these needs.
The users of information systems are demanding integration. CIM is a tool currently suggested to integrate the information of a manufacturing company.

The software technology for a completely integrated CIM system does not yet exist. A robust software interface is required to integrate all of the statistical process control, quality analysis, and manufacturing management software. [C.37]

**CIM consists of a number of building blocks.** These building blocks do not need to be implemented in the sequence they are discussed in this study but can be rearranged as the organization prefers.

The building blocks are:
- Computer-Aided Design — CAD.
- Computer-Aided Manufacturing — CAM.
- Material Requirements Planning (MRP) and Manufacturing Resource Planning (MRP II).
- Just-In-Time (JIT) inventory management.

These building blocks need to be combined to form CIM.

We propose a further extension to CIM that will eliminate the lack of external information, one of the major problems with CIM. The organization, in this case the manufacturer, can link its information systems with other organizations whom it supplies or who supplies it. The author refers to this as **Inter Organization Information Sharing (IOIS).**
The implementation of IOIS does not have to follow CIM, even though IOIS will deliver its maximum potential if it follows CIM. IOIS can be implemented today by centering the discussions between chain members less on price and more on information exchange. The types of information to be exchanged are open to negotiation between chain members. Limited information sharing can start now by for example, automated re-ordering facilities. So IOIS does not need to wait for CIM.

In the following chapters the different building blocks of CIM are discussed. CIM is discussed in more detail, as well as the IOIS concept the author proposes.

-oOoo-
CHAPTER 5.

COMPUTER AIDED DESIGN.

"The history of information technology can be characterized as the overestimation of what can be accomplished immediately and the underestimation of long-term consequences."

Strassmann, Information Payoff

5.1. Introduction.

This chapter examines Computer Aided Design.

Computer Aided Design (CAD) is the single most productive tool used by computer users. It increases labour productivity by a factor of 2.5. The average time to draw a plan declines by 30 - 70%, and the number of design steps is reduced by an average 40%. [B.8]

As is evident, the savings induced by CAD are enormous. Automation of the design process is very advanced. Future areas of expansion in CAD are the use of artificial intelligence and computer simulated testing of products. In computer-
simulated testing no scale model has to be built, as tests are performed on the computer by using pre-defined models. The engineer can study the performance of the product and redesign it in a short time. Costs are reduced not only because of the faster design, but because the building of models should become obsolete.

The term CAD can refer either to Computer Aided Design or Computer Aided Draughting systems. CAD must be defined to clarify this.

5.2. Definition of Computer Aided Design.

Computer Aided Design (CAD) can be defined as the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. [B.7]

The computer systems consist of the hardware and software to perform the specialized design functions required by the particular user firm. The design process consists of a number of steps.

These steps are:

- Definitions of the problem.
- Construction of the product that will address the problem.
- Analyse the design and optimize it.
- Evaluate the design, to see if it resolves the problem.
- Obtain approval of the design, design the formal product, and pass it on to the manufacturing department.

These steps are illustrated in Figure 5.1.
The question which arises is: What is the role of the computer during design?

The computer has three basic functions during design: a) It must assist the designer to remember things better; b) it must support the analytical and logical power of the designer; and c) it must carry out all the repetitive tasks. [D.18] The role of the computer is graphically represented in Figure 5.2.
Applications of Computers In the Design Process

![Diagram showing the applications of computers in the design process](image)

Source [8.7]

Fig. 5.2.

The designer is more creative, and innovative, and his experience is used to its full extent.
The difference between Computer Aided Design and a Computer Aided Draughting system is that a Draughting system cannot analyze the drawing. [C.31]

A CAD system commonly employs a minicomputer. A typical CAD workstation includes a graphics display unit, a number of interactive devices, such as alphanumeric keyboard, function keys, tablet, mouse or joystick, a graphic digitizer as well as a plotter for a hard copy. [D.18]

Benefits of CAD include [B.8]:
- Reduction in design lead times.
- Economies in design and draughting.
- Economies in material usage.
- Ability to design products which are too complex to be designed manually.

The following section looks at the origins of CAD.

5.3. The origins and development of CAD.

The first technological breakthrough for CAD was the refresh screen plus lightpen. This allowed interactive control between the user and the screen. This system was developed by SAGA in the 1950's. [B.7]

General Motors instigated the first industrial application of CAD with its Design Augmented by Computer (DAC) program in 1959. Lockheed and McDonnell aircraft firms followed shortly thereafter. [B.8]
Later, in the 1960's, the US Department of Defence played an important role in disseminating the virtues of CAD. They held the first conference in this regard.

The military became preoccupied with the concept of an automated design and manufacturing environment in the 1970's. The Air Force Integrated Computer-Aided Manufacturing (ICAM) program in 1979 led to the establishment of a committee to implement common software standards which allow different CAD/CAM systems to communicate with each other.

The computer has become a tool without which an engineer would be stranded and completely unproductive. With it, the designer can be more creative and innovative, and his experience is used to its full extent.

For the sake of comprehensiveness, the following section will discuss CAD software packages in South Africa.

5.4. CAD applications available in South Africa.

There are quite a few CAD software packages available in South Africa. Some are either public domain or comprehensive commercial packages. Some of the public domain software are — DanCAD3D, Easydraw, PC-Draft-CAD, VGACAD and many more.

The following commercial packages available in South Africa are discussed: they are AutoCad and ALLYCAD.
5.4.1. AutoCAD — Release 11.

AutoCAD is the industry-standard design and drafting software for desktop computers. The reasons why AutoCAD has been so popular are its open architecture, embedded programming language, C-language programming environment, and extensive platforms and peripheral support.

AutoLISP is an easy-to-use programming language embedded in AutoCAD. AutoLISP allows one to tailor AutoCAD to meet specific design requirements. It allows one to create solutions ranging from simple, macro-like routines for customizing menus and automating command sequences to fully integrated applications programmes.

AutoCAD includes a number of features that streamline data transfer between AutoCAD platforms and between AutoCAD and other software products. AutoCAD's file portability features allow the direct transfer of AutoCAD drawing files to any machine running AutoCAD regardless of the operating system; no conversion is required. There is complete upward compatibility, enabling drawing files created with any previous AutoCAD release to be used with AutoCAD Release 11.

AutoCAD supports the Drawing Interchange File (DXF) format for exchanging drawings with most other CAD packages. For added flexibility it also supports the Initial Graphics Exchange Specification (IGES) format used by numerous design and engineering packages.
Hardware Configuration.

AutoCAD Release 11 is available on 286 and 386 PCs under DOS, Sun SPARC stations, DEC station 3100 and 5000 machines and Macintosh II computers.

5.4.2. ALLYCAD.

ALLYCAD is a full draughting system with wide range of functions including:
- Elements.
- Geometry lines.
- Auto hatching.
- Advanced dimensioning.

ALLYCAD has links to the following packages:
- AllyWord – Link to any word processor.
- AllyStruct – Link to structural and finite element analysis.
- AllyLink – Link to other CAD software.
- AllyBase – A link to DBase III.
- AllyMech – Link to MRP and NC software

Hardware Configuration.

ALLYCAD runs on MS-DOS and PC-DOS systems, UNIX and supports a wide range of mice, digitizers and plotters.
5.5. The use of Artificial Intelligence in Design.

As already stated in Chapter 2, a knowledge engineer practises the art of bringing the principles and tools of artificial intelligence research to bear on difficult application problems requiring expert knowledge for their solution.

The industrial revolution saw the automation of mechanical power. The introduction of computers saw the automation of calculation. Now, knowledge engineering brings the automation of reasoning. [B.1]

Computer Aided Design has almost reached its final technical objective, to improve man-machine communication. All known algorithms for design are automated in CAD. [B.8] There are, however, future tasks that need to be addressed, those which use non-numeric and non-algorithmic computations. These tasks are addressed by Intelligent CAD systems.

The objectives of an intelligent CAD system is to increase productivity and to decrease errors. As products become more complicated and larger, designers will need more computer supports for the full scope of the design process including the thinking process. [B.1]

The design of a product must go through certain design stages.

The design stages are [B.1]:
- Conceptual design.
- Basic design.
- Detail design.
- Production design.
- Prototype.
- Testing.

The different stages of change are discussed below.

Conceptual design is the process whereby the designer must think of alternatives from given specifications. These specifications are input from customers and suppliers.

This stage in the design process takes the longest time. Any time savings here will reduce costs dramatically. A better design will reduce the likelihood of new product failure.

During basic design, the designer decides on the layout and structure of the design.

The application of current off-the-shelf CAD systems is in the detail design stage. Here the detailed specifications of the parts are decided. [B.1]

Production design is the link between a Computer Aided Design system and a Computer Aided Manufacturing (CAM) system. The data necessary for production is developed here. A standard interface must be put into place, so that the CAD system and the CAM system can communicate inter-actively.

Feedback from the computer aided manufacturing system is essential during trial manufacturing and testing.

A major problem with conventional CAD systems is the lack of assistance and standard interfaces, as the designer needs a great deal of assistance during the basic design phase. [B.8]
Intelligent CAD systems can help the designer to refine customer specifications. This problem can be addressed by linking current CAD's with Databases and Expert systems.

The designer must use large volumes of data in order to create a successful design. The data is entered by humans, and the omission of data or the inaccuracy of input can cause enormous errors. Reducing the amount of data the Computer Aided Design system needs and linking the system to other machines will reduce the risk of errors.

5.6. Specifications of future CAD systems.

The system should support the designer in all the stages of design. There must be room to implement knowledge gained by experience.

Specifications must be screened, so that the designer can concentrate on the problem at hand. [B.5]

Data must be moved from one design stage to the next without losing meaning. [B.2] This must be done in such a way that it assists the designer in the design process.

The man-machine interface must support innovations and new ideas. [B.3] The machine must be able to detect errors as soon as possible to save time and money.

The Computer Aided Design system must have link or interfaces to other systems which can serve as inputs or outputs to these systems. [B.2] There must at least be a direct interface to the computer aided manufacturing system and the customer service system.
5.7. Summary.

Design is the first phase in the development of a product. Since the product life-cycle of most products is condensed and new products need to be developed at an ever increasing rate, the risk of product failure is high. One way of reducing the risk is by identifying products that are going to fail as early as possible, preferable during design when the money spent on the product is minimal.

This chapter has examined an important part of Computer Integrated Manufacturing namely Computer Aided Design. A few commercial packages available in South Africa were discussed, as well as the future use of AI in CAD software.

The following chapter looks at another part of the CIM “pie” – Computer Aided Manufacturing.
CHAPTER 6.

Computer Aided Manufacturing.

"Direct labor goes on-line."

Taylor, What every engineer should know about AI

6.1. Introduction.

This chapter gives a short introduction to Computer Aided Manufacturing. Concepts relevant to manufacturing, such as What is manufacturing? and What are its functions are discussed. Applications commercially found in South Africa are scrutinized.

Computer Aided Manufacturing (CAM) is factory-floor-level automation. CAM includes all the computer numerically controlled machines, programmable controllers, robots, automated materials-handling equipment, assembly equipment, and inspection equipment – all linked together with hardware and software to manufacture a product automatically. [C.31]

Manufacturing machines development preceded modern computer technology. Owing to the fact that computer applications in manufacturing only started to appear in the late 1960's,
communication between manufacturing machines and computers is only fairly recent. [B.7]

Design systems preceded manufacturing systems. CAD systems are more portable and easier to install and use than CAM systems. This has led to greater support for CAD systems than for CAM.

The contribution of computers to the design process is more evident than in manufacturing aspects. Design of a product precedes production; errors in design are more critical and of greater financial importance than production due to the cost involved. The risk of errors in production is smaller than in design.

Computer Aided Design’s functions are easier to generalize. For example, most design activities require facilities for handling pictures. In contrast, the manufacturing process tends to vary significantly from company to company, thus requiring more flexible systems.

6.2. What is manufacturing?

Manufacturing is the process of transforming inputs into outputs. Inputs are typically the following: Raw material, labour, equipment, tools and energy. Outputs can be both physical or not. [C.30]

Physical output is the production of products that have a certain value. Non-physical outputs are services like consulting. The inputs must be minimized and the outputs must be maximized for the organization to be productive.
In Figure 6.2. the input arrow is considerably smaller than the output arrow, indicating that inputs must be minimal and outputs maximal. See also section 6.3.

Manufacturing can be broken down into three basic types: continuous processing, custom or job shop, and batch processing. [C.23]

In the graph[Figure 6.2] a few of the factors that determine which production method is used in the organization, are mentioned. Some of these are production volume, rate of production, and skill level.
6.2.1. Custom or job shop manufacturing.

This type of manufacturing is usually encountered at a build-to-order company. [C.6] The process is either highly specialized or uses a high component of technology. [C.23]

The distinguishing feature of job shop production is low volume. The manufacturing lot sizes are small, often one of a kind.
This production method is used to meet specific customer orders, there is a great variety in the type of work which needs to be done by the manufacturer.

The production system must be flexible and general purpose to allow for this variety of work. Flexible production means that personnel must be well trained so that they can perform a range of different work assignments. Examples of products manufactured in a job shop include aircraft, machine tools, and prototypes of future products. [C.9]

6.2.2. Batch production.

The bulk of manufactured goods is made by this method. Products are made in batches.

This category involves the manufacturing of medium-sized lots of the same item or product. The lots may be produced only once, or they may be produced at regular intervals.

The purpose of this production method is often to satisfy continuous customer demand. The product is manufactured in order to build up inventory. When the inventory level falls below a certain level a batch of this product is scheduled.

Manufacturing equipment used in batch production is general-purpose but designed for higher rates of production. It has been estimated by Groover [C.30] that as much as 75% of all parts manufactured are in lot sizes of 50 pieces or less. Hence, batch production and job shop production constitute an important portion of total manufacturing activity.
6.2.3. Mass Production.

In a mass production cycle, raw material is converted into a product with as little work in progress as possible. The process is continuous from start to finish and there is a constant movement of stock (inventory). [C.23]

Mass production is characterized by very high production rates, equipment that is completely dedicated to the manufacturing of a product, and very high demand rates for the product.

Not only is the equipment dedicated to one product, but the entire plant is often designed for the exclusive purpose of producing the particular product. Investment in machines and specialized tooling is high.

6.3. Functions in manufacturing.

For any of the three types of production there are certain basic functions that must be carried out to convert raw materials into finished product. Figure 6.4. illustrates the five functions in the manufacturing process.

6.3.1. Processing.

Here a product is transformed from one state of completion into a more advanced state of completion. An important point to remember is that no materials or components are assembled or added to accomplish the transformation. Instead, energy is added to change the shape of the part, remove material from it, or alter its physical properties. [C.44]
Most manufacturing processes require five inputs:
- Raw materials.
- Equipment.
- Tooling and fixtures.
- Energy.
- Labour.

The manufacturing process adds value to raw materials. It is carried out by using the five inputs.
The manufacturing process produces two outputs: completed product or scrap and waste. The five inputs and two inputs are graphically illustrated in Figure 6.4.

6.3.2. Assembly.

Assembly and joining processes constitute the second major type of manufacturing operation. In assembly, the distinguishing feature is that two or more separate components are joined together. In fabrication of a product, assembly is preceded by the processing operation. [D.18]
6.3.3. Material handling and storage.

Means to move and store materials between the processing and assembly operations must be provided. In most plants, materials spend more time being moved and stored than being processed. In some cases, the majority of the labour cost in the factory is consumed in handling, moving, and storing materials. It is thus important that this function be carried out as efficiently as possible. [D.32]

6.3.4. Inspection and testing.

The purpose of inspection is to determine whether the manufactured product meets the established design standards and specifications.

Testing is generally concerned with the functional specifications of the final product rather than the individual parts that go into the product. Final testing of the product ensures that it functions and operates in the manner specified by the product designer. [A.15]

6.3.5. Control.

The control function includes both the regulation of individual processing and assembly operations, and the management of plant-level activities. Control at the process level involves the achievement of certain performance objectives by proper manipulation of the inputs into the process.
Control at the plant level includes effective use of labour, maintenance of equipment, moving materials in the factory, shipping products of good quality on schedule, and keeping plant operating costs at the minimum level possible. [C.8]

6.4. Definition of Computer Aided Manufacturing (CAM).

"Computer-aided manufacturing (CAM) is defined as the effective use of computer technology in the planning, management, and control of the manufacturing function." [C.30]

Computer-aided manufacturing (CAM) includes all the computer numerical control machines (CNC), programmable controls, robots, automated materials-handling equipment, assembly equipment and inspection equipment—all linked together with hardware and software to manufacture a product automatically. [C.31]

CAM can be defined in two broad categories: Manufacturing planning and Manufacturing control.

6.4.1. Manufacturing Planning.

The computer is used indirectly to support the production function. The computer provides information for the effective planning and management of production activities.

Indirect applications refer to those there is no interface between the computer and the manufacturing process. [C.23]
The information function of Manufacturing planning includes process planning, master scheduling, requirements planning and capacity planning.

- **Process planning.**

  Here the sequence is determined for individual processing and assembly operations needed to produce a part. [B.5]

- **Master scheduling.**

  Master scheduling is a listing of the products to be made, when they are to be delivered, and in what quantities. [D.26] Based on this schedule, the individual components and subassemblies that make up each product must be planned. [C.4]

- **Requirements planning.**

  Raw materials and parts must be ordered from suppliers, and all of these items must be planned so that they are available when needed. This task is called requirements planning or material requirements planning. [D.12] For a more detailed discussion see chapter 8.

- **Capacity planning.**

  The master scheduling must not list more quantities of products than the factory is capable of handling, given their current resources. The production quantity that the factory is capable of producing is referred to as plant capacity. Capacity planning is concerned with the planning of the manpower and machine resources of the firm. [C.30]
There are quite a few applications of computers in the manufacturing environment.

The following is a list of important applications:

- Cost estimating.
  
The task of estimating the cost of a new product has been simplified in most industries by computerizing several key steps required to prepare the estimates. [E.1]

- Computer-aided process planning (CAPP).
  
  Process planning is concerned with the preparation of route sheets. The route sheet lists the production operations and associated machine tools for each component of the product. It is a list of operations and work centre required to produce the product. [B.5]

- Computerized machineability data systems.
  
  One of the problems in operating a metal-cutting machine tool is determining the speeds and feeds that should be used to cut a part. Computer programmes have been written to recommend the appropriate cutting conditions to use for different materials. The calculations are based on data that have been obtained either in the factory or laboratory which relate tool life to cutting conditions. [C.44]

- Production and inventory planning.
  
  The computer has found widespread use in many of the functions in production and inventory planning. These functions include maintenance of inventory records, automatic reorde-
ring of stock, production scheduling, maintaining current priorities for different production orders, material requirements planning, and capacity planning. [C.9]

6.4.2. Manufacturing Control.

Manufacturing control is concerned with managing and controlling the physical operations in the factory. [C.23]

This is a direct application in which the computer is involved directly in the manufacturing process for the purpose of monitoring or controlling the process.

Manufacturing Control includes the following functions: shop floor control, inventory control and quality control.

- Shop floor control.

Shop floor control is concerned with the problem of monitoring the progress of products as they are being processed, assembled, moved, and inspected in the factory. The use of scheduling falls in this realm. The system must schedule which machine does what at what time. This requires that the parts be scheduled one by one through the various production machines on the route for each part. The system's performance will be influenced by how close the true progress is to the scheduled progress. [C.30]

- Inventory control.

As could be expected, inventory control attempts to strike a proper balance between too little inventory and too much inventory. [D.1]
Quality control assures that the quality of product and its components meet the standard specified during product design. The success depends on inspection on an ongoing bases during the manufacturing. [C.10]

For the sake of completeness, the following section will discuss CAM software packages in South Africa.

6.5. CAM applications available in South Africa.

There are quite a few CAM software packages available in South Africa. The following commercial packages available in South Africa are discussed: Kinetix and AutoCAM.

6.5.1. Kinetix.

Kinetix is a flexible decision reinforcement tool for manufacturing. It is easy to use; query feature helps to extract the data one needs from multiple data sources. Then its powerful presentation tools strengthen one's decisions by helping one analyze that data.

Features:

- **Point-and-click query definition.** Automatic point-and-click menu options save time and effort by helping one write queries to a data base quickly and efficiently.

- **Integrated presentation tools.** Control charts, trend charts, histograms, scatter plots, text and graphic reports and spreadsheets add flexibility to one's analysis, enabling one to see
relationships and draw conclusions one might have missed before.

Interfaces to the following databases:
- Allbase – version 2.0; 3.01 and 7.0.
- ORACLE – version 5.1 and 6.0.

Software required.
- HP-UP 6.5 or 7.0.
- ARPA/Berkeley Networking Services.

Hardware Configuration.
- HP Model 340 or higher.
- A minimum of 12 Mb RAM.
- A minimum of 35 Mb of disk space. Total swap space should not be less than 40 Mb.

6.5.2. AutoCAM.

AutoCAM helps one to programme one's NC machine and helps verify the accuracy of the programme. AutoCAM lowers scrap rate and increases NC Machine productivity.

Features:

If can choose from 4000 custom post-processors, and perform multiple set-up jobs. It automatically generates whole patterns due to links to CAD.

It automatically calculates spindle speeds and feeds, and completely control all machining operations.
AutoCAM allows one to generate hundreds of similar programmes from one master programme for families of parts.

**Hardware Configuration.**

AutoCAD Release 11 is available on 286, 386 or 486 PCs under DOS, 1.2 Mb diskette, 20 Mb hard disk, math coprocessor and at least a EGA graphical display unit. It requires AutoCAD.

### 6.6. Summary.

This chapter has examined what manufacturing is and the different functions during manufacturing. The term Computer Aided Manufacturing (CAM) was also defined, and two software packages commercially available in South Africa were discussed.

For any CAM software to be effective it must have links to CAD software. In the following chapter the combining of CAD and CAM is discussed.
Chapter 7.

COMBINING CAD & CAM.

"The Blacker the Better."

Taylor, What every engineer should know about AI

7.1. Introduction.

In this chapter the combining of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) is referred to as CADCAM.

This chapter highlights the difference between CADCAM and CIM. The main advantages and disadvantages of CADCAM are discussed. Some tips about how to implement CADCAM successfully are debated.

The term computer integrated manufacturing (CIM) is often used interchangeably with CADCAM. While the terms are closely related, using the terms interchangeably is incorrect, as CADCAM and other functions are only subsets of CIM. [C.23] In the graph it can be seen that CIM encompasses both the manufacturing and the design process.
Scope of CADCAM and CIM.

Source [C.30]

Fig. 7.1.
It should be noted that CADCAM is an integration of design and manufacturing activities by means of computer systems. The purpose of CADCAM is to integrate the independent CAD and CAM computer systems. This reduces duplication of effort by design and manufacturing personnel.

With CADCAM, a direct link is established between product design and manufacturing.

### 7.2. Components of a CADCAM system.

This section looks at the components of CADCAM.

The data generated during CAD become the starting point and form the initial data base for production, manufacturing and industrial engineering in developing the process plans. [C.31] The activities included in CADCAM are illustrated in Figure 7.2.

The computer must be used as a tool. It must be a means to an end and not an end in itself. The computer must assist people in being creative and innovative. [B.7]

People that are the key resource must be optimized. The computer must automate repetitive tasks that frustrate experts and make them unproductive. A expert's knowledge must be used to maximum effect. The swapping of ideas must be fostered.
Fig. 7.2.
7.3. Advantages and disadvantages of CADCAM.

7.3.1. Advantages of CADCAM:

In order to gain the maximum benefits of CADCAM the advantages and disadvantages should be known. The presiding section discusses this.

• Reduced production lead time.

Lead time is the time needed to set up the manufacturing path for a specific product. [C.44] The lead time is reduced because products that are manufactured in a similar fashion can be scheduled, one after the other.

• Faster response to requests for quotation.

Because the automated islands are linked there will be a quicker response to clients needs. There is no need to have a paper trail and a computer trail. [C.28]

• More evenly distributed workload.

If the design process were automated, it would be completed faster than manufacturing can handle. [C.28] This will create a backlog of information that needs to be imported into the manufacturing process.

• Transcription errors minimised.

The fact that a person must feed the system the information leads to a grave risk of Garbage In Garbage Out. [C.21] Garbage In Garbage Out occurs when there is an error during the
information capturing phase. The error goes undetected and influences the result of any calculations performed on the inconsistent data.

This risk and loss of integrity is minimized by using automated links between the components of the CADCAM system. [D.18] The exchange of information and ultimately knowledge is encouraged. The quality of decisions is much higher due to the fact that the decision is based on a broader base of information.

• Better cost control.

Management can see where the problem areas are that need to be addressed. [C.34] They do not need to wait for reports any more, as the information can be directly printed out from the system. This will lead to more timely and accurate information.

• More customer input into designs.

The design process is much easier and the need to redesign products is less. [B.8] The hands of the designer are free to design products more appropriate to the customers' needs and wants.

• Materials and machining time saved through optimized algorithms.

The scheduling of machines can be optimized by using proven and well tested algorithms. [D.26] The company only needs to customize algorithms to suit their own specific needs.
• Engineering manpower reduced.

Past mistakes can remembered by the system, which will ensure that the same mistakes are not made twice. [D.28] The scheduling of machines can be done by computers.

7.3.2. Disadvantages of CAD/CAM.

The following are stumbling blocks in the way of implementing CAD/CAM successfully.

These stumbling blocks can be divided into the following categories:

a) The organisation has not considered taking up new technology.

b) The technology has been considered and rejected.

c) CAD/CAM is installed, but not fully used.

a) The organisation has not considered taking up new technology.

Francis [B.7] notes that research has shown that successful companies are those which constantly monitor new developments. Consequently, those companies which are not looking at CAD/CAM are probably behind in other areas as well.

Companies must not get on the bandwagon just for the purpose of automation, as the latest technology is not necessarily custom made for the company.
There are major costs involved in being in the forefront of the latest technology, not only the direct cost of equipment, software and other cost but also hidden costs like risk of failure, internal conflict in the company, and apprehension on the part of co-workers.

b) The technology has been considered and rejected.

Francis concluded that rejecting CADCAM may be the correct decision for some companies, particularly when the technological application is highly elaborate and complex, or when it is an entirely novel application. [B.7]

A great deal of commitment, both from management and workers, is needed to instigate change, even more so when it affects the company as a whole. Preconceived ideas regarding the technology may affect the criteria for evaluation.

The criteria used to evaluate a particular technology may be completely wrong or irrelevant, especially if the benefits that can be achieved are not quantitative.

c) CADCAM is installed but not fully used.

The following factors affect the utilization of an installed system:

The facility is inappropriate for the task. [C.28] A lack of commitment by the user and the developer during the design phase will lead to indifferent user requirements.

Users fear the facility and prefer to use conventional methods. [F.14] Few people accept change without any apprehension.
User training must be provided, as well as adequate time to phase out conventional methods. The phasing out must be in accordance with a phasing out plan.

Where users have the choice of using conventional methods or new technology, they continue to use conventional methods because they do not have time to learn the new techniques.

Conflict between the providers of the system and the users. Users fear the change that is about to take place. The user feels he is no longer of any use to the company, which leads to conflict. Management must address this problem in order for the project to succeed. [F.15] The problem with management commitment is that they do not know what the system is supposed to do, how the system (computer system) is to function, who should be in control of the system and whom it will affect.

7.4. A successful CADCAM system.

User support is critical for the success of CADCAM system. Innovation is more successful when it is introduced by somebody influential in the company like top management. [F.18] As mentioned in section 7.3, commitment by both management and the work force is very important in order for the CADCAM system to be effectively implemented and used. The following points can help the company in the transitional phase. [B.7]
7.4.1. Develop a total awareness plan.

All the users must know what will happen when the CADCAM system is complete. [F.15] They must know if their jobs are at risk and if their job description is going to change.

The developer of the system must suppress the urge to automate for the sake of automation; the worker's job must be made easier. Information technology is only a means to an end and not an end in itself. The computer must support innovative thinking.

7.4.2. Develop a implementation plan.

Management must decide when and how the system will be implemented. There are five conversion strategies that management can follow to implement the new CADCAM system.

The following conversion strategies are suggested by Kendall and Kendall. [F.21]

Conversion Strategies:

Direct changeover. On a predetermined date the old system stops and the new one is activated. The new system can only be successful if extensive testing and training is done beforehand. This strategy forces the use of the new system. There are grave risks involved in this strategy: long delays might ensue if errors occur, and users may resent the fact that they are being forced to use a new and unfamiliar system.
Parallel conversion. The new CADCAM system runs parallel to the old system. This type of conversion is costly and chances of success scant. The users of the system will prefer to use the old system because they know it already. In this type of environment where users are dependent on others' performance it is impractical to use this conversion strategy.

Phased conversion. The old system is gradually replaced by the new system. In the CADCAM environment the new system could be used to do specific projects or products.

Modular conversion. Only part of the old system is automated. This is a ideal environment to use this type of conversion strategy, by first implementing a CAD system, then a CAM system, and then integrating the two. It takes time to implement, but due to the enormous costs involved it is better to spread the costs over a longer time period.

Distributed conversion. A new system is built at a specific location. If it is successful, then it is implemented at new locations.

7.4.3. A system use and development plan.

If the system follows the modular conversion strategy there must be a plan for software engineers to develop the next module of the ultimate system. [F.21]
7.4.4. A user training and designer orientation plan.

User training is very important. Adequate time and funds must be made available to train the users and help them to adapt to the new system. [F.20]

7.4.5. A system audit and monitoring scheme.

Constant monitoring of the system is of utmost importance to see how the system performs and how it affects the users' performance. [F.17]

7.5. Considerations to implement CADCAM.

The following must be considered before the CADCAM system is purchased or developed.

Consider possible expansions that may be required in the future. There must be a facility to add onto the system. This is essential in the light of constantly changing and expanding user needs.

Expertise will be needed to develop, implement, run, and modify the system. This expertise must be present in the company or easily acquired at reasonable costs. When the system is implemented, its effect on the users and the company's resources must be explored. It must be remembered that automation does not necessarily lead to less work, but it only changes the character of the work.

In the manufacturing arena numerous islands of automation need to be linked together to form a coherent whole. In order
for the company to be vendor independent hardware and software that supports this viewpoint must be selected. In South Africa this is especially true, with big international companies disinvesting in the country.

The current processor power of the company, hardware resources, must be taken into account so that the maximum benefits can be gained from it. In short, the system must fit the current and future hardware resources of the company.

Compare your needs with available systems. If well tested systems do exist that fit your needs, buy them rather than trying to develop themselves. It is not cost effective to re-invent the wheel each time you need one.

For the sake of comprehensiveness, the following section will discuss a CADCAM software package available in South Africa.

### 7.6. Application of CADCAM in South Africa.

There are quite a few CADCAM software packages available in South Africa. The following commercial package available in South Africa is discussed: MicroDUCT.

#### 7.6.1. MicroDUCT.

MicroDUCT is the means of entering into 3D design and manufacture complex shapes at the minimum level of investment. It provides the toolmaker and the product designer with key features of a 3D modelling system and machining system. Each of these systems are discussed later.
Benefits of using MicroDUCT.
- Shorter lead times by elimination of modelmaking and copy-milling.
- Improved quality from accurate and repeatable Computer Numeric Control (CNC) machining.
- Elimination of need to interpret 3D shapes from 2D drawings.
- Ability to machine the most complexly structured shapes.
- Fast NC programming and full utilization of CNC capabilities.

Features of the modelling system.
- Powerful command language and easy-to-use screen menus.
- Generation of both geometric and sculptured surfaces.
- Automatic blending and intersection of surfaces.
- Scope for extensive surface manipulation.

Features of the machining system.
- Full 3D machining.
- Allowances for contraction, spark gap and wall thickness.
- Machining instructions for punch and die from one computer model.
- Support for ball nose, slot drill and radius slot drill cutters.

Hardware Configuration.

Runs on an industry standard IBM compatible 386 computer.
7.7. Summary.

CADCAM is not a "Turnkey" graphical computer system; it encompasses much more than the mere design of a product. The manufacturing of the product is also addressed. [B.2]

In the past the emphasis was on the design process, this has moved to the manufacturing process, and will move to the integration of the two in the future.

CADCAM systems promote the viewpoint that the design process and the manufacturing process are part of a continuum which forms the product life-cycle.

The goal of a CADCAM system is to reduce the various time elements in the product life-cycle. [B.7] If this goal is met, we are able to increase productivity and improve our standard of living. These time elements spring from duplication and needless conversion from one system to another, from CAD to CAM.

Owing to the fact that more than one user need is addressed; CADCAM is an environment and not just a software program. Like any environment it should be managed.

The following chapter will address the problem of Material Requirements Planning.
Chapter 8.

Material Requirements Planning.

"The greater the information component of a product, the more likely the manufacturer is a market leader."

Michael Porter

8.1. Introduction.

This chapter scrutinizes Material Requirements Planning - MRP and Manufacturing Resource Planning - MRP II.

MRP was first introduced in the 1960's. [C.6] Companies that first used MRP were J.I. Case, Twin Disc, Black & Decker and Perkin-Elmer. These were pioneering firms who helped in the creation and development of MRP. APICS played a decisive role in the early 1970's. [D.18]

MRP begins with the items listed on the Master production scheduling (MPS) and determines the quantity of all components and materials required to fabricate those items and the time that the components and material required. [C.6], [D.12]

MRP is accomplished by "exploding" the bill of materials and offsetting requirements by the appropriate lead times. [D.12]
Material Requirements Planning (MRP) is a computational technique that converts the master schedule for end products into a detailed schedule for raw materials and components used in the end products. The detailed schedule identifies the quantities of each raw material and component item. It also indicates when each item must be ordered and delivered so as to meet the master schedule for final products.

Parts already in stock are taken into consideration in determining which parts still need to be manufactured. Backward scheduling is then used to calculate when production of the parts required should commence. [C.6]

The concept of MRP is relatively straightforward. What complicates the application of the technique is the sheer magnitude of the data to be processed. Each product may contain literally hundreds of individual components. These components are produced from raw materials, some even use the same raw materials.

This chapter is concerned specifically with Material Requirements Planning (MRP).

- Where MRP fits into the organisation.

- Definition of MRP.

- How MRP works.

- Advantages and Disadvantages of MRP.

- Whether MRP reduces inventory.
8.2. Where Material Requirements fit in.

It is necessary to see where Material Requirements Planning fits into the broader organisational context.

**Long-range planning.**

Long-range planning activities include business forecasting, product and market planning, production planning, and financial planning. As can be seen Fig. 8.1, these activities are interdependent. [D.3]

**Medium-range planning.**

Medium-range planning activities include distribution requirements planning, demand management, master production scheduling (MPS), rough-cut capacity planning, material requirements planning (MRP), and capacity requirements planning. [D.12]

**Short-range planning.**

Short-range planning and control involve both priorities and capacities. Demand management provides the gross requirements' input to the MPS, which drives the short-range planning system. The MPS and MRP provide priority planning. The output of the MPS and MRP must be within capacity constraints and determined by Capacity Requirements Planning. Capacity control is obtained via input/output controls.
MRP in the Organisation

Long Range

- Business Forecasting
- Organisation Objectives
- Product and Market Planning
- Financial Planning

Medium Range

- Distribution Requirements Planning
- Production Planning
- Master Production Scheduling (MPS)
- Rough-Cut Capacity Planning

Short Range

- Demand Management
- Material Requirements Planning
- Capacity Requirements Planning
- Final Assembly Scheduling
- Production Activity Control
- Purchase Planning & Control

Fig. 8.1.
Priority control is achieved through production activity and purchasing controls. [D.12]

Fundamental concepts with regard to MRP will be discussed now.

8.3. **Fundamental concepts in MRP.**

Material requirements planning is based on several concepts. These concepts are: a) independent versus dependent demand, b) manufacturing lead time and c) common use items.

8.3.1. **Independent versus dependent demand.**

The distinction between independent and dependent demand is important in MRP. Independent demand for a product is not directly related to demand for other items. End products and spare parts are examples of items whose demand is independent. Independent demand patterns must usually be forecast. [C.30]

Dependent demand means that demand for the item is related directly to the demand for some other product. Component part and raw materials are good examples. Once the delivery schedule for end products is established, the requirements for components and raw materials can be directly calculated.

MRP is a technique used for determining quantities of dependent demand items. These items constitute the inventory of manufacturing; raw materials, work-in-process, component parts, and subassemblies.
8.3.2. Manufacturing lead time.

The lead time for a job is the time that must be allowed to complete the job from start to finish. There are two types of lead time in MRP: ordering lead times and manufacturing lead times. [D.18] [C.30]

An ordering lead time for a item is the time required from initiation of the purchase requisition to the receipt of the item from the vendor. Raw material usually has a shorter lead time than products that are fabricated.

Manufacturing lead times for a item is the time required to fabricate the item. Manufacturing lead time is made up of Queue time, setup time and run time. [D.18] The components of manufacturing lead time are illustrated in Figure 8.2.

![Manufacturing lead time diagram]

Fig. 8.2.
Queue time is the amount of time allocated for a production lot to wait in the queue with all other lots that are scheduled for the next machine.

Setup time is also referred to as "make ready time". This is the time needed to set up the machine for the production run. This time will vary, depending on the condition of the machine and what run preceded the run in question. This will affect the inspection time and tear down time. Inspection time is the time needed to inspect the machine to see whether it is still in running condition. Tear down time is the time that it takes to replace part of the heads of the machine for the new production run.

Run Time, is the time during which the machine performs the operation of actually manufacturing the product.

8.3.3. Common use items.

Common use items are raw materials and components that are used on more than one product. MRP collects these common use items from different products to effect economies of scale in ordering the raw materials.

8.4. Input and Output of Material Requirements Planning.

MRP requires a few inputs and outputs. The inputs are a) Master production schedule, b) Bill of material file and c) Inventory status file. The outputs are purchase and production planning. The inputs and output of Material Requirements Planning are illustrated in Figure 8.3.
8.4.1. Inputs of Material Requirements Planning.

The inputs of Material Requirements Planning are discussed here.

a) Master production schedule.

Master production schedule is a listing of what end products are to be produced, how many of each product are to be produced, and when they will be ready for shipment. [C.28] An example of a master schedule is shown in the graph below. The
time period of the schedule is in weeks, and will depend on a company's specific production rates. If the rate is high then a smaller time interval is required; and a longer time interval is necessary if the rate is low.

### Master Production Schedule

<table>
<thead>
<tr>
<th>MPS for products P1 and P2 showing weekly delivery quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week number</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td><strong>Product P1</strong></td>
</tr>
<tr>
<td><strong>Product P2</strong></td>
</tr>
<tr>
<td><strong>Etc.</strong></td>
</tr>
</tbody>
</table>

Fig. 8.4.

Product demand in the master schedule can be separated into three categories: [C.30]

The first category consists of customer orders for specific products. These orders usually include a delivery date that has been promised to the customer.

The second category is forecast demand. This is based on statistical techniques applied to previous demand patterns. The forecast must constitute the major portion of the master schedule.

The third category is demand for individual components. These are repair parts and are stocked in the firm's service...
department. This category is sometimes excluded from the master schedule since it does not represent demand for end products.

b) **Bill of material file (BOM).**

Bill of materials file is used to compute the raw material and components requirements for end products. The end products information is received from a list from the master schedule. Bill of materials provides information on product structure by listing the raw material, components, parts, and subassemblies that make up each product. [C.24] It gives information on the building blocks of the product. This is illustrated in the graph.

![Product Structure (Bill of Material)](image)

Fig. 8.5.
Level 0 of the graph is the product that is to be manufactured. It is made up of subassemblies S1, S2, and S3. In order to make the master scheduling easier end products must be a minimum on level 0. Different products can use the same raw material, components and even subassemblies. Although each of these are shown separately in Figure 8.5., they can be combined in any manner at any level of product structure (BOM).

The bill of materials should be structured as follows:
- It should lend itself to forecasting of optional product features. [D.18]
- It should permit the MPS to be stated in the least end items. [D.18]
- It should lend itself to the planning of subassembly priorities. [C.30]
- It should permit easy order entry.
- It should be usable for final-assembly scheduling.
- It should lend itself to efficient computer file storage and maintenance.

A bill of materials is complex if [D.19]:
- There is a large number of end products that are candidates for the master production schedule.
- Each product uses a large number of different materials.
- The materials composition of each product is, to some extent, unique.

A bill of materials is simple if [D.19]:
- There are very few materials even if there is a large number of products.
- Most materials are common to most end products.
c) Inventory status file.

Inventory status file is divided into three segments. The first segment is called the item master data segment and provides the item's identification (part number) and other descriptive data regarding the item.

Part numbers may be significant or not. A significant part number is intended to convey certain information such as the source of the part, the material used in the part, the shape, the use or function of the part, and so on.

The second segment, called the inventory status segment, gives a time-phased record of inventory status. In MRP, it is important to know not only the current level of inventory, but also future changes. Therefore the inventory status segment lists the gross requirements for the item, scheduled receipts, on-hand status, and planned order releases. The third segment provides subsidiary data such as purchase orders, scrap or rejects, and engineering changes. [D.16]

An ABC analysis of the inventory items is usually done. The inventory is classified by usage-value. Each inventory item is placed in decreasing order of annual, monthly or weekly Rand volume. The time span will depend on how rapid the stock turn-around time is. The inventory is now divided into three classes, called A, B, and C.

Class A contains the items with the highest annual (or approved time span) Rand volume. These items receive the most attention. Medium class B receives less attention, and class C
which has the lowest annual rand volume, receives only periodic attention. [D.18] & [D.32]

Factors that affect the importance of the item include the following:

[D.3]. [D.2]

- Annual rand volume of the transactions.
- Unit cost
- Scarcity of raw material, components or parts used in producing the item.
- Availability of manufacturing resources, manpower, and other facilities needed to produce the product.
- Lead time.
- Stability of the demand for the product. If demand varies a much higher inventory is necessary.
- Cost of stock-out. How sensitive is the user of the product when out of stock occurs?
- How often is the product redesigned? How often do competitors redesign the item?

8.4.2. Output of Material Requirements Planning.

The MRP programme generates a variety of outputs that can be used in planning, more specifically purchase and production planning, and managing plant operations. [D.12]
The outputs include:

- Order release notices, which provide the authority to place orders that have been planned by the MRP system.
- Report of planned order releases in the future.
- Re-scheduling notices, indicating changes in due dates for open orders.
- Cancellation notices indicate that certain open orders have been cancelled.
- Reports on inventory status.
- Performance reports of various types, indicating costs, item usage, actual versus planned lead time, and so on.
- Exceptions report, showing deviations from the schedule, orders that are overdue, and so on.
- Inventory forecast, indicating projected inventory levels in the future.

8.4.3. How MRP works.

As already mentioned in 8.4.1., material requirements planning operates on the data contained in the master schedule, bill-of-materials file, and inventory status file. The master schedule specifies a period-by-period list of final products required. The BOM defines what materials and components are needed for each product. The inventory status file contains information on the current and future inventory status for each component. The MRP programme computes the volume of each component and raw material needed by exploding the end product requirements into successively lower levels in the product structure. [C.30]

The use of object oriented programming is ideal here.
Referring to the master schedule in Fig. 8.4., 25 units of product P1 are specified in the master schedule for week 7. Now referring to the product structure in Figure 8.5., 25 units of P1 explode into 50 units of subassembly S1 and 100 units of S2 and the following numbers of units for the components:

- C1 : 50 units
- C3 : 50 units
- C5 : 200 units
- C2 : 200 units
- C4 : 200 units
- C6 : 100 units

The example above is graphically illustrated in Figure 8.6.
The quantities of raw materials for these components are determined in a similar manner.

There are two factors that complicate the MRP parts and materials explosion [C.30]:

First, the components and subassembly quantities given above are gross requirements. Quantities of some of the components and subassemblies may already be in stock or on order. Hence, the quantities that are in inventory or scheduled for delivery in the near future must be subtracted from gross requirements to determine net requirements for meeting the master schedule.

A second factor that complicates MRP is common usage items. Some components and raw material are common to several products. The MRP processor must collect these common use items during the part explosion. The total quantities for each common use item are then combined into a single net requirement for the item.

8.5. Critical evaluation of MRP.

8.5.1. Advantages of MRP.

Some of the important advantages are listed here.

* Reduction in inventory. A certain degree of stock management is better than none at all. This is discussed in more detail in section 8.6.

* Quicker response to changes in demand than is possible with manual requirements planning systems. The results of MRP
are more accurate and more quickly obtained than a manual system. [D.6]

- Reduced setup and product changeover cost. Everything is planned ahead so everybody knows what to do, which makes them more productive. [D.19]

- Better machine utilization. The bills of material gives all relevant information so that the final assembly schedule can make maximum use of available machines. [D.24]

- Improved capacity to respond to changes in the master schedule, and as a aid in the development of the master schedule. Because MRP is directly linked to the master production schedule the response in the MPS is very fast. [D.22]

8.5.2. Disadvantages of MRP.

To get the maximum effect of MRP you should be aware of the main disadvantages.

- One of the main criticisms of this approach is that it assumes that the lead time for each part is fixed. [C.6]

- The date at which production should commence is determined, assuming infinite capacity. There is no attempt to consider the current capacity; investigations to see if the capacity is sufficient do not exist. [D.6]

- MRP is data intensive or data hungry. Input data must be accurate. MRP does not have functions that test the integrity of the data. If the bill of material is not accurate, too much or
not enough of a product will be manufactured. According to Greene [D.18] accuracy of 98 percent or greater is necessary, or else the right requirements cannot be exploded down through the lower levels. This is also the case with inventory. A good MRP system needs an inventory record of 95 percent or better. This is a good example of GIGO — garbage in garbage out. [C.23]

The master production schedule (MPS) is the master of material requirements planning. If the MPS is not managed well, the other activities will not overcome this weakness. [C.30] Even today, a typical company will have unrealistic master scheduling. This is because too many companies put their "hope and dreams" into the MPS rather than what they can do.

The MRP system is a batch system. [D.18] It is not interactive and the result are out of date the minute they are generated. It cannot respond to unforeseen changes. It does not change the computational parameters on an interactive basis.

8.6. Does MRP reduce inventory?

There is a disparity in the literature regarding the issue whether MRP reduces inventory or not. Anderson and Schroeder found in their survey of 326 companies that implemented MRP increased annual inventory turnover from 5.6 times to 9.5 times. [D.13] McClain of the Rawling Sporting Goods Company reported an inventory reduction of 25 percent while inventory turnover increased from 2.9 times to 5.4 times per year. [D.14]
Aggarwal has suggested that anywhere from 2000 to 5000 US companies were using MRP-based systems. [D.15] He cites Black and Decker as a successful example of its implementation. They made substantial improvements in engineering change orders, surplus and obsolete materials and components, and past-due receipts from suppliers.

However, it is obvious that not everyone is deliriously happy with MRP. Aggarwal reported that 90% of MRP users were unhappy with its performance, especially in the area of inventory management. [D.15]

Sadowski cites that the MRP crusade which occurred during the 1970's resulted in a large number of actual implementations and a large amount of experience being gained rapidly, primarily through failures. [D.7]

Hendry [C.6] states that there is a high rate of failure between 80-90%. The success stories are mostly attributed to the correct addition of planning modules - they include priority scheduling rule, lot sizing rules and buffering decisions - and the integrations of functions. These functions are typically production, accounting and marketing, the firm is also able to keep the large amount of data needed for the system up-to-date. [D.19], [C.6]
8.7. Manufacturing Resource Planning (MRP II).

MRP II was developed in the 1970's due to the inadequacies of the MRP system. This system incorporates the MRP methodology with other modules to create the master schedule for capacity planning and shop floor control. [C.6]

Since MRP II is much harder and more complex than MRP, it has been much harder to implement and to date has not achieved the level of acceptance or support MRP enjoys. [C.23]

In Figure 8.7, a schematic representation is given which shows the major functions that make up an MRP II system. Material requirements planning was the function put in the first place. It is, however, not an independent system. Until it was expanded, both up and down, we lacked the ability to establish a realistic plan and then to convert it to the detailed actions required to carry out.

By tying MRP together with capacity-requirements planning and the master production schedule with adequate feedback a closed loop is achieved. In order to make the master schedule realistic it needed to be linked to the production plan. The production plan has a role in achieving the business plan so this was also included. [D.18]

The one additional characteristic of a good MRP II system is the capability to run simulations to evaluate the consequences of alternative plans and/or trade-offs for determining the best choice when not all choices can be satisfied.
Manufacturing Resource Planning (MRP II)

- Business planning
- Production planning
- Master production scheduling
- Material requirements planning
- Capacity requirements planning
- Realistic?
- Executing capacity plans
- Executing material plans

Source [D.18]

Fig. 8.7.
A number of exciting extensions of MRP II are still occurring. An increasing number of manufacturing companies are providing their suppliers with planned orders. This will aid the suppliers in managing their businesses better. This is referred to as vertical integration.

A vertical integrated system can be defined as a rationalized and capital intensive network designed to achieve technological, managerial, and promotional economies through the integration, coordination, and synchronization of marketing flows from points of production to points of ultimate use. [D.20]

A short vertical channel is made up of a supplier, a manufacturer, distributor (shop), and an end user. A system that is vertically integrated is one in which there is an agreement between players in the same vertical channel to exchange information.

If the end user joins in the agreement and has a good MRP II system this will lead to demand being dependent and no longer independent. Dependent demand can be calculated where independent demand must be forecast.

The most recent development centers on simulations. Once a company has both an operating and a financial system that work, contingency planning becomes practical. It enables the company to predict the consequence of alternative plans, and to answer "what if" questions. Being warned of the consequences ensures that better decisions will be made.

Oliver Whight, who helped promote MRP and led its growth into MRP II, also established criteria for evaluating an MRP
II system. By answering 25 questions, a company can rate itself as an A, B, C, or D user. [D.21] See table 8.1 for the 25 questions.

Table 8.1.

<table>
<thead>
<tr>
<th>ABCD Check List.</th>
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<tr>
<td>Questions.</td>
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<td>Answer Yes or No to the following :</td>
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<tr>
<td>1. Inventory record accuracy 95% or better.</td>
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<td>2. Bill of material accuracy 98% or better.</td>
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<td>3. Routing accuracy of 95% or better.</td>
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<td>4. Initial education of at least 80% of all employees.</td>
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<td>5. An ongoing education program.</td>
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<td>6. Time periods for Master production scheduling and Master Requirements Planning are weeks or smaller.</td>
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<td>7. Master production scheduling and MRP run weekly or more frequently.</td>
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<td>8. System includes firm planned order and pegging capability.</td>
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<td>9. The master production schedule is visibly managed, not automatic.</td>
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<td>10. System includes capacity requirements planning.</td>
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<td>11. System includes daily dispatch list.</td>
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The class D user simply has MRP II running on a computer. Management is not using the information. Most of the systems cost has been expended but no or very few paybacks are achieved.

The class C user orders material, but out in the factory hot lists still exist. The system is simply a order launch with limited paybacks.

The class B user not only orders through MRP II, but also uses MRP II to reschedule both factory and purchase orders. There
are major improvements in deliveries, inventory turn around, and productivity.

The class A user has three characteristics beyond a class B user: a) there is a link between the financial planning system and the operating system (MRP II); b) the company has the ability to simulate and evaluate alternative plans; c) general managers and staff are using the information provided by the MRP II system to help manage the business.

8.8. MRP II software in South Africa.

8.8.1. HORNET.

HORNET is a project management system for microcomputers.

Hornet can be used to plan a wide range of projects, large or small. No constraints have been placed on the system to restrict its use to a particular type of project or working environment. A major organisation in South Africa that is currently using HORNET is SpoorNet.

Hornet can be used to manage a large, complex single project or a series of small, independent projects which may or may not make up a large project. The only restriction on the size of the project it can handle is dependent on your computer configuration, the number of sub-projects being considered and the range of resource calculations and printed reports being used. [F.11]

Hornet will dynamically allocate the available storage space to the project until all disk space has been exhausted. Many management projects have between 200 and 1000 activities, with
four or five resource based calculations. Large complex projects may have as many as 3000 activities.

Hornet considers individual networks, each consisting of up to 255 activities. Each network may be built up out of a 'sub-network', and these networks may be linked together to define overall network logic. A global network or NETWORK ZERO as referred to by Hornet, is used to represent and link all sub-networks together. Each sub-network is represented by an activity in Network Zero, thus giving a two level hierarchy to the project. [F.11]

The way in which projects are defined by networks and sub-networks, can give management a wide range of information from detailed control of certain sections of the project, to overall summary reports.

Activities within each network are referenced by number and are given descriptions, management code and a type definition code. Estimated duration of the activity and any preceding activities are specified. Network logic is defined by specifying a list of preceding activities for each activity.

Three types of links are available: a usual sequential link where one activity follows another, and start/start and finish/finish links allowing activities to be run in parallel or "Hammocked" together. A "hammocked" activity represents an activity whose actual duration is not related to its work content but is dependent on other activities being worked on at the same time. [F.12]
All logic links have optional time delays allowing activities to be overlapped or a specific time period allowed to elapse before work starts on a subsequent activity. Inter-network links are identical to normal precedence links and require no special labelling of the activities involved.

External constraints may also be included in the network by use of target start and finish dates. These dates impose specific constraints on an activity to start or finish on a specific date.

A project date is applied to all networks to monitor progress and ensure the network follows the progress of the project.

**RESOURCE CALCULATIONS.**

Hornet has a powerful and comprehensive range of resource calculations. There are 128 separate resource types or resource centres for each project.

Each resource is considered to be valid in all sub-networks based within the project and is given a description, limits of availability and optional factor. There are two limits of availability, normal availability and total availability. The two limits are clearly shown on all resource reports and are used by the scheduler when re-scheduling is done. The factor allows resource allocations to be increased or decreased by a global multiplication factor.

Each activity may have up to eight resources allocated to it. There is a Resource Spreadsheet that helps with the calculation of resources and is used for other selection criteria.
THE SCHEDULER.

The scheduler section of Hornet offers global time analysis calculation for the project and resource scheduling. The global time analysis gives a complete time analysis schedule for the project, all sub-networks are considered, and Network Zero (master network) is updated. The scheduler also includes the resource scheduling facility.

REPORTING.

Hornet has two forms of reporting, on screen reports and printed reports. Hornet gives standard format network reports for time scheduling, bar charts, and data lists.

Selective report/s may be obtained, based on a range of activity numbers, data range, degree of activity and management code.

HARDWARE.

Hornet runs on a IBM compatible PC.

The system requires at least 210 K memory but 380 K is recommended.

Two floppy drives or a floppy drive and a hard drive are required.

SOFTWARE.

MS-DOS Version 2 or higher.
8.8.2. RAPIER.

Rapier is an asset management system. It is based on the most advanced relational database technology and the use of 4GL tools. Rapier was developed to cover a highly diversified range of customer requirements.

Rapier is completely hardware and operating system independent. It is compatible with industry development standards and can easily be linked to other corporate systems.

The basic modules cover a wide variety of functions including:
- Asset management.
- Work management.
- Materials management.
- Purchase management.
- Finance management.
- Project management.
- Inspection module.
- A maintenance strategy development tool.

Rapier has received wide acceptance within many diverse sectors of industry including:
- Brewing.
- Construction.
- Power generation and public utilities.
- Shipbuilding.
- Electronics.
- Steel.
- Airlines.
- Heavy and light engineering.
8.9. Summary.

MRP II integrates financial planning, marketing, engineering, and purchasing through the simple mathematical tools of MRP.

Both MRP and MRP II require that every employee be thoroughly and strictly disciplined about entering data into the system. This will prevent the GIGO (Garbage in Garbage out) effect.

The next chapter examines Just-in-Time inventory policy.
Chapter 9.

Just-in-Time.

"Look for something that should be there but isn't; look for something that shouldn't be there but is."

Carrol, Computer Security

9.1. Introduction.

This chapter examines Just-in-Time — JIT inventory keeping policy.

In the strict sense, being just in time means having only the correct part in the correct place at the correct time. This is unattainable due to machine, human, and other errors. The ideal is to compress production lead time as much as possible.

JIT production has come to mean, in the broadest sense, a philosophy of manufacturing which strives to produce with the shortest possible lead time and the fewest possible mistakes. [D.18]

The most basic approach is to examine why inventory is needed and to eliminate as many of the reasons for it as possible. With
little or no inventory, material moves unimpeded from raw
material to a finished product.

The existence of inventory is an indicator of waste. Waste is
defined as any unnecessary use of material, labour, space,
equipment, or energy. Thus any activity that does not add
value to a product is waste.

The basic idea is to reduce inventory in selected areas by drain­
ing excess inventory, reducing lot sizes, and reducing lead
time. Then how to change the methods of management, to
permit the same production volume to take place with less
inventory, is examined.

The most important part is to change the physical processes of
production and to alter all kinds of management practices
which require inventory or which add to lead time. Materials
management is a part of this total effort, but only a part. Many
of the corrective actions extend to such activities as plant
layout, operator training, reduction of defect rates, reducing
setup time, and so on. The ideal is to improve the manufactur­
ing process itself, both the physical process of production and
its preparatory activities.

It is the constant improvement which is the most important
part of JIT production.

Just-in-Time is really a management philosophy which impacts
on every aspect of manufacturing, from marketing practice to
supervision of the plant work.
The JIT concept was developed in Japan and has been very successful in the Toyota company. [D.17] & [D.25] See section 9.4 for more information.


Just-in-Time is a commitment to the minimization of inventory while remaining reliant on demand of pull materials through the factory; the orientation of a company towards 'zero defect' and the minimization of machine set-up time; the nurturing of a workforce that is able to operate under the flexible regime demanded by JIT; and the fostering of a 'total quality' orientation throughout the organisation. [D.6]

Customer demand is the driving force of JIT. As customer demand increases, the materials required increase. This is illustrated in Figure 9.1.

---

**Internal and external JIT environment.**

![Diagram of internal and external JIT environment]

**Fig. 9.1.**
Anthony Dear [D.31] formulated the following simile with regards to JIT, when he compared inventory flow to the water flow of a river.

Figure 9.2.(A) shows a stream with an uneven bottom: there are pools that are not moving on the bed of the stream. In Figure 9.2.(B) the bed has been levelled and the water flows through quickly. This linear flow is the ideal in JIT. Not only is the total amount of water in the stream decreased but the time taken for it to flow through is shortened.

**Inventory flow as a stream**

(A) - Just-In-Case

---

(B) - Just-In-Time

---

If the bed of a stream is uneven (as in a) then there is:
- small throughput of water
- much water in the system

If the bed is levelled (as in b) more water gets through even though there is less water in the stream.

Fig. 9.2.
A further point is that the turbulence which causes interruption of the water flowing in Figure 9.2.(A) is a direct result of the pockets of stagnant water at the bottom of the stream. In a similar manner accumulation of stagnant Work-in-process (WIP) is not only wasteful in that it represents unused money, but it also slows down the operation. [D.31]

Working towards JIT means working towards a constant flow of inventory through the manufacturing operation. This means shorter lead times and lower stocks. The use of buffers to guard against uncertainty should be used selfishly and only as a last resort.

9.2.1. Elements of a JIT program.

The following are elements of a JIT program. They are listed first and then discussed.

Elements of JIT:
- Workplace organisation.
- Quality improvements.
- Reduced setup times.
- Reduced lot sizes.
- Preventive maintenance.
- Gradual inventory reduction.
- Reduced space for less material travelling.
- Multi-functional workers.
- Standardization of jobs.
- Excellent preparation for production
- Leveling the schedule.
- Balancing operations.
9.2.2. Discussion of elements of JIT.

Each of the elements of JIT are discussed here.

square Workplace organisation.

All unnecessary elements in the production process are omitted or removed. By inspection and organizing the workplace, only the tools, material, and supplies which is required at a specific work location, are kept. This helps the movement of the stock and the uncluttered repair of machines.

square Quality Improvement through Process Capability Improvement.

The production process should be capable of producing items without defects. This implies statistical process control as well as the incorporation of standard methods for preventing defects from entering into the regular procedures. [C.36]

This is the essence of total quality control. There is several ways in which it is achieved [D.18]:

square Immediate Feedback. This method involves measuring items as quickly as possible after they are made and stopping to make corrections. This implies that the operation is so well known that immediate corrective actions can be taken. The shorter the time between production of a part and its use, the more likely it is to associate the discovery of a defect with its cause.
Fall-Safe methods. These are mostly methods of overcoming human errors. A check digit is a way in which information typed into a computer can be validated.

- Capability of tools and equipment much better than required for parts made.
- Development of excellent methods of isolating causes of defective production and other production problems.

Reduced setup times.

Setup time refers to the machine's down-time for preparing the machine to produce a new part. When setup time is reduced, labour time usually is also reduced.

Setup time is reduced by making setup a standard, routine procedure. This requires practice, and practice comes from making setups regularly. This leads to smaller lot sizes.

Short setup times are an indicator that everyone thoroughly understands how the production process works and is capable of doing any task at any time.

There are four major steps in reducing setup times: organize to do as much as possible with the machine running, modify tools and equipment in simple ways, eliminate adjustments, and practice. [C.6]

In a job shop company it is not so easy to reduce the setup time, because parts are not made in large numbers. Thus not all the elements are known and workers will have less practice.
Reduced lot sizes.

Small lot sizes follow from the practice of frequent setups. They aid the practice of immediate feedback for quality improvement. If production is defective, not so much is made, and it is easier to organize the work areas if very little material is present.

Small production lot sizes also call for small transport lot sizes. It is desirable to reduce the time between making and using a part, which is facilitated by reducing both the lot sizes transported and the transport distance.

The emphasis is on the reduction of transport time, making transport as effective as possible and reducing the risk of damage.

Preventive maintenance.

Preventive maintenance is very important for both quality and reduced setup times. The purpose is to preserve the capability of the tools, instruments, and equipment. [C.23] It is not to spend a little money on a regular basis to avoid having to spend a lot in a lump sum. Preventive maintenance does spread the money needed over time, but it also reduces the indirect cost due to machine breakdowns. These indirect costs include the loss of productivity of the labour force, customer dissatisfaction due to stock outs, and delays caused to other production processes.

Time for preventive maintenance needs to be built into the schedule.
Gradual inventory reduction.

The major reason for reducing inventory is to reveal the problems which require the excess inventory. Inventory is permanently kept low only by having successful methods for attacking and overcoming the problems which surface.

Reduced space for less material traveling.

The reduction in space begins with the first steps of workplace organization and extends to major layout changes which reduce the distance between machines whenever possible.

Two major benefits are the reduced travel distance for material inside a plant and the improved visibility of operations.

One way greatly to reduce space is the use of cell manufacturing. There are two basic kinds of cells [C.20]: (1) U-shaped transfer line in which equipment is positioned so that parts move one at a time in sequence; and (2) flexible cells in which jobs are not processed in any particular machine sequence. Jobs are kept in a local work-in-process pre-setup inventory and are sent to the correct machine in the cell as it becomes open.

The most common example is a flexible machining cell in which the workpieces are automatically transported and loaded, and in which control is maintained by a computer dedicated to the cell. The U-shaped transfer line is much more likely to be used with repetitive manufacturing.
Multi-functional workers.

The workers must increase both the breadth and depth of their skills. [D.6] Rotating workers help to keep job satisfaction at a premium.

Excellent preparation for production.

Active production in the plant is the test of whether adequate preparation was made for production. Many of the large problems which surface are due to the lack of preparations of certain functions.

Levelling the schedule.

Levelling of schedule is when the production process of all the parts are equally distributed over time. [C.17] It is only possible if there is a repeating pattern of demand for the parts or products.


9.3.1. Advantages of JIT.

Due to the reduction of redundant stock, less stock has to be moved, stored, counted and checked so there are lower indirect costs. [F.20]

Quality problems are detected more quickly, because of smaller batches. [C.9]

Delays, errors, bottlenecks and other problems become much more visible with JIT. This means they can be more easily
solved, leading to smoother production and an increase in worker involvement and motivation. [D.31]

The following are major disadvantages of JIT.

9.3.2. Disadvantages of JIT.

- One of JIT's prime objectives is to reduce the lot sizes and to reduce the time needed to produce the final product for the consumer. If the factory is not correctly designed it has to be redesigned to reduce the time products spend on the production line. The cost of redesigning the factory can be enormous. [C.9]

- If delivery is to be made Just-in-Time, then it is necessary to plan in plenty of time. [C.6] Planning ahead is easy if the demand is stable and the products produced stay the same. This is only the case in a make to stock company. It is clearly not possible in a make to order company. A make to order company does not have stable demand and the mix of products varies considerably.

- JIT is a system that has been designed for a make to stock company and not for a make to order company. [C.6] & [C.9] Although some of the elements may be appropriate, the vital control modules required for customer enquiry are not offered by JIT.

9.4. Applications of JIT.

Awareness of the possibilities offered by Japanese management techniques is, perhaps, the strongest in the realm of
production and inventory management where few practitioners could have escaped encountering the concept of Just-in-Time (JIT) manufacturing. [D.6]

The Toyota production line is the best known application of JIT.

In 1980 the inventory period of Toyota Motor Company was a mere 4 days, material included. The safety margin was 64%, which means Toyota can earn a profit even if the present sales were to drop to 64%. It must be added that Toyota has consistently achieved these figures over the past several years, and in some cases even bettered them. [D.17]

The Toyota production system or KANBAN was developed and promoted by the Toyota Motor Corporation. [D.25] The main purpose of the system is to reduce costs; the system also helps to increase the turnover ratio of capital (total sales/total assets) and improves the total productivity of a company as a whole.

Although cost-reduction is the system’s most important goal, it must achieve three subgoals in order to achieve its primary objectives. [D.17]

These subgoals include:

1. Quantity control, which enables the system to adapt to daily and monthly fluctuations in demand, in terms of quantities and variety.

2. Quality assurance, which assures that each process will supply only good parts or subassemblies.
3. Cultivation of human resources while the system utilizes the human to attain cost objectives.

To realize these goals, Toyota has established the following systems and methods:

- Kanban system to maintain Just-in-Time production.
- Production smoothing method to adapt to demand changes.
- Shortening of setup time for reducing the production lead time.
- Standardization of operations to attain line balancing.
- Improvement activities by small groups and the suggestion system to reduce the work force and increase the worker's morale.
- Visual control system to achieve independent defect control.
- System to promote company-wide quality control.

Many people call the Toyota production system a Kanban system, but this is incorrect. The Toyota production system is a way to make products, whereas the Kanban system is a way to manage the Just-in-Time production method.

A Kanban is a tool to achieve JIT production. It is a card usually put in a rectangular vinyl envelope. Two kinds of Kanbans are mainly used: a withdrawal Kanban and a production-ordering Kanban.

A Withdrawal Kanban specifies the kind and quantity of product which the subsequent process should withdraw from the preceding process. A Production-ordering Kanban specifies
the kind and quantity of product which the preceding process must produce.

Kanban rules:

Rule 1. The subsequent process should withdraw the necessary products from the preceding process in the necessary quantities at the necessary point in time.

Rule 2. The preceding process should produce its products in the quantities withdrawn by the subsequent process.

Rule 3. Defective products should never be conveyed to the subsequent process.

Rule 4. The number of Kanbans should be minimized.

Rule 5. Kanban should be used to adapt to small fluctuations in demand (fine tuning).

Subrules:
- Any withdrawal without a Kanban should be prohibited.
- A Kanban should always be attached to the physical product.

9.5. Combining JIT and MRP II.

A theme has emerged within the major trend towards JIT in the manufacturing environment: to adapt MRP II to include features of JIT. [D.6] & [D.26]

The driving force behind this is the large amounts of capital invested in current MRP II systems; reluctance on the part of management to rebuild the manufacturing control environment; and an inherent fear for running out of stock.
MRP is usually represented in daily time buckets. It is a "push" system. This contrasts with JIT which is a "pull" system. [D.26]

The strength of conventional MRP II systems is in planning while the strength of JIT is in execution. [D.26]

The fear of stock outs is a result of the major advantage of a Just-in-Time system, that there is always more than enough inventory even though the demand may vary considerably. The following section highlights the divergence between Just-in-Time and Just-in-Case.

**Just-In-Time versus Just-In-Case.**

The ideal of Just-in-Time (KANBAN in Japanese) is to have the part available at the next stage of processing the instant that stage is ready for the part. [C.23]

The ideal of Just-in-Case (JIC) on the other hand, is that parts are made in advance in case something goes wrong with the previous process so that there is enough in stock to continue. The result is that parts are made for stock and not for the consumer. JIC is based on the forecast demand for a product and not the actual demand.

With Just-in-Time the part must be of high quality and must be delivered as promised. A delivery delay can cause the shut down of the entire operation. This simply must not happen. Scheduling must be perfect and machines must be in perfect working condition. [C.23]
Extensive analysis of machine functions, tool requirements, and all other aspects of the system is required. This will lead to contingency planning; breakages are anticipated and steps are taken well in advance to minimize the effect of the break.

JIT versus JIC

![Diagram showing JIT and JIC](image)

Fig. 9.3.

The graph (Figure 9.3.) illustrates ideal JIT and JIC production systems. In the case of JIT demand is equal to the company's capacity. The average demand for a product coincides with the company's ability to produce the product over time.
In a JIT system the capacity of the company is equal to the maximum demand. This is not the case in a JIC system, where the average demand must equal capacity.

The transition from a JIC manufacturing strategy to a JIT strategy needs time. Both management and the work force need the time to adapt to the new JIT strategy.

The underlying philosophy of MRP (Material Requirements Planning) is Just-in-Case.

JIT simply raises its overall capacity to accommodate fluctuations in demand, either by increasing throughput or adding more productive cells. This contrasts with MRP which responds to fluctuation in demand by juggling production between fixed capacity. [D.6]

The primary distinction between the two is that JIT is a simple and highly efficient but basically static production scheduling system which can only operate as long as the parameters in the internal and external environment remain fixed or change at a constant pace, whereas MRP assumes that both environments form part of an inter-relationship and attempts to operate in a dynamic mode by making optimising decisions based on forecasts.

MRP has the inherent ability to accommodate uncertainty in the external environment. It is weaker in dealing with shop floor scheduling while the strength of JIT lies directly in the rigour with which it can reduce operating cost and exercise control on the shop floor. Thus a system that integrates MRP and JIT must seek to integrate the forecasting, planning and
optimising benefits of MRP and the efficient and simple shop floor management discipline of JIT.

Herein lies the fundamental challenge of integrating MRP with JIT principles. The task must be to reconcile not only two fundamentally different philosophies (JIT and JIC) but two different approaches to data processing. JIT can make minor adjustments within the limits set by stable parameters of supply and demand. MRP is a batch processing operation which periodically reassesses and resets those parameters in order to provide the manufacturing system with enough material in plenty of time.

Integrating these two approaches throughout an organisation may be feasible but unless and until MRP can operate interactively with the manufacturing process on a real time basis, it will be the shortcomings of MRP and not the advantages of JIT that will set the limits of the systems performance.

Combining MRP and JIT represents a system heavy solution and, as such, it is still prone to many of the problems MRP-only systems suffer. By 'throwing more system' at a problem the problem becomes cluttered with unnecessary system information which complicates the implementation and maintenance of the system. The risk of GIGO — Garbage In Garbage Out — is high due to the fact that intensive manipulations are done on the data.

The goal of Just in Time is to achieve zero inventory. There should be no raw material stocks, no buffer stocks on the shop floor and no warehouse full of finished goods. [C.6]

The subsequent chapter discusses inventory management.
Chapter 10.

Inventory Management.

"A forecast is nothing more than a leap of faith into the future."

Wheeler, Strategic Management

10.1. Introduction.

Inventory is important for all parts of the organisation. A marketer needs finished products to supply to clients; manufacturing needs raw material and parts to make finished products; and partially finished products influence production effectiveness. [F.17]

Inventory is usually a large scale investment. Silver et. al state that: "... on average, 34 percent of the current assets and 90 percent of the working capital of a typical company in the United States are invested in inventories. In addition, considerable labor costs (clerical and managerial) are incurred in the control of inventories." [D.1] Thus, we see that even small percentage reduction in costs will be transformed into huge absolute savings.
If inventory is optimum for a specific company, then sales will increase, productivity will increase, and production costs will decline. This will all lead to the improvement of profit.

The wrong inventory level can lead to a catastrophic result: high investment costs, low productivity, and low user satisfaction.

10.2. Reasons for keeping inventory.

The supplier of goods must estimate what the demand for a certain product will be. As with any estimation there is uncertainty, and the greater the uncertainty the greater the risk. The greater the risk, the more inventory is needed. Uncertainty is the product of uncontrollable factors in the macro and micro economy.

These factors include the following: political instability, stay-aways, uncertainty of future monetary policy of the government, and sudden change in consumer demand. These factors not only influence the company directly, but also indirectly via consumers, competitors, suppliers, and distributors.

10.3. Critical evaluations of inventory.

10.3.1. Advantages of inventories.

Keeping of inventory has certain advantages for the organization. These are: lower unit costs, more effective production, better delivery and avoidance of scrap.
1. **Lower unit costs.**

Goods are produced in batches. There are setup costs to produce a batch. These costs have a direct influence on the unit cost of the product. There is a disparity here: the larger the batch, the lower the setup cost per unit, but the longer it takes to setup the machine, the longer it takes to sell the product. Long selling time will lead to greater risk and susceptibility to forecast error. Machine setup time will be long due to the inexperience and lack of practice on the part of the operators.

Too much inventory will lead to higher storage and administration cost as well as higher financial costs. The law of demand states that there is an inverse relationship between price and quantity demanded. Stated differently, as the price increases, the quantity demanded decreases; and the other way round if prices decrease. [E.2] By reducing unit costs the price of the product can be reduced, thus stimulating demand for the product.

2. **More effective production.**

Raw material stock protects the manufacturer against varying supply. If the company has a just-in-case inventory policy it can manufacture stock during low demand periods for high demand periods. [D.2] This will help to reduce the maximum capacity needed by the company.

Each industry has a standard delivery time. The company must at least match this time or rather better it. The company can reduce its delivery time by reducing lead time and setup time. [D.3]

4. Avoidance of obsolescence.

Inventory must be low enough so that if there is an engineering change, the organisation can scrap the inventory with minimum cost. This will create a climate for innovations and will keep the company on the cutting edge of its specific sector. [D.32]

10.3.2. Disadvantages of inventories.

In the political uncertainties of South Africa inventory is the manufacturer’s only hedge against stay-aways and sanctions. This hedge against uncertainty, however, has a cost.

Inventory cost is not only the amount paid for inventory, and the finance cost which is needed to supply inventory to the next person in the chain. Inventory cost is not singular but consists of many indirect costs.

Some of these costs are: the costs to store, to secure, to administer, and to keep the stock fresh. The capital that is spent on indirect and direct inventory costs can be used to finance other more profitable projects.
1. **Inventory carry cost.**

Inventory cost consists of: Costs of capital; cost of storage; cost of special storage packages; cost of security; costs due to loss of inventory; cost of insurance; cost due to robbery; costs due to both physical and technological ageing.

2. **Less adaptable to engineering and manufacturing change.**

New designs by the company's engineers or by competitors can cause large amounts of stock to be written off. [C.25] If the company decides to postpone the new development, competitors can gain a substantial market share, which will reduce demand for the product and may even lead to permanent reluctance on the part of the consumer. The postponing of new product introduction will create the image that the company is not interested in the idea, which can impede innovative ideas.

3. **Danger of system instability.**

Everybody in the distribution channel is interdependent. [D.3] For example: AAA, a small trader, experienced a small increase in the demand for product XYZ, say from 75 to 85 units. He decides to order 95 units in case the growth continues.

BBB, a wholesaler, sees that AAA has a increase from 75 items of XYZ and decides that this is a growth in the product. BBB decides to order 120 of XYZ. This is a increase of 45 units.
CCC, a manufacturer, sees that the demand for XYZ has increased by 45 units and decides to produce 60 units more than normal. If the demand was only accidental, the following period’s demand will drop substantially. This will have the same effect as an increase, except in the opposite direction. The longer the distribution channel, the greater the danger of system instability. Change in demand will only be exaggerated further down the distribution channel.

The manufacturer has a duty to inform everybody in the channel and to help them to decide whether the demand increase is actual or only accidental.

4. Increased autocracy.

The implications are not only financial; they also increase autocracy. [D.4] The organisational structure becomes cluttered with unnecessary lines of management. The company is not as flexible as it could be, which causes a loss of market share and its competitive edge.

5. Forecast error.

Both sales and demand estimation errors might occur. Estimation is very difficult if the company has a lot of diverse products. Each product must be evaluated separately, but what complicates the whole process is the fact that a product can be an input for another. [D.32]

The maximum time interval of the estimation is unlimited, but the longer the time span the greater the risk of a wrong estimation. This is referred to as estimation error. To minimize this
error regular reviews must be done and the estimations must change to suit the changing circumstances.

10.4. Inventory cost.

Inventory cost is a combination of the following: Order cost, Delivery cost, Setup cost, Out-of-stock cost, Cost incurred to prevent out-of-stock situations, Carry cost, Administration cost and Security cost, and other indirect costs. [D.2]

Order cost. Each time an order is placed certain processes take place in the purchasing department. This cost is the cost incurred to place the order.

Delivery cost. The delivery cost is the cost to deliver products or raw materials. That is the costs to transport the ordered products.

Setup cost. The time to prepare the machine for production.

Carry cost. The costs of storing and protecting the stock.

10.5. Specific inventory management systems.

There is a wide range of inventory management systems. They are discussed here.

An effective inventory system will accomplish the following [D.32]:
- Ensure that sufficient goods and materials are available.
- Identify excess and fast- and slow-moving items.
- Provide accurate, concise, and timely reports to management.
• Expend the least amount of cost in accomplishing the first three tasks.

There are six vital areas to be considered when choosing a inventory system [D.32]:
• The development of demand forecasts and the treatment of forecast errors.
• The selection of inventory models (EQO, EOI, EPQ, MRP or SOQ)
• The measurement of inventory costs.
• The methods used to record and account for items.
• The methods for receipt, handling, storage and issue of items.
• The information procedures used to report exceptions.

The use of sophisticated mathematical techniques per se does not necessarily result in an effective system. Precise, highly mathematical techniques are of little use unless the information to feed into the models is available at a realistic cost and is relatively accurate.

It is difficult to classify the various inventory control systems in an orderly fashion. Nevertheless, it is possible to distinguish among the systems most frequently used.

Common types of inventory systems are perpetual, two-bin, periodic, optional replenishment, and materials requirements planning. The perpetual, two-bin, periodic, and optional replenishment system usually apply to end items, while the material requirements planning system applies to materials and components used in production. [D.32]
The level of stock must be monitored on a regular basis. If the stock level reaches a certain point more stock must be ordered. This level is referred to as the re-order point.

This point is a combination of lead time and buffer stock. Lead time is the amount of stock which will be needed before the delivery of the new stock has taken place.

Safety stock is extra stock that the company holds in case the delivery is delayed or the demand varies suddenly. Safety stock is illustrated in Figure 10.1.
10.5.1. Perpetual inventory system.

A perpetual system keeps record of the amount of stock in storage, and replenishes it when the stock drops to a certain level. This system is based on the concept of economic order quantity (EOQ see 10.7) and reorder point.

Under this system the reorder point and order quantity are fixed, the review period and demand rate are variable, and the lead time can be fixed or variable. [D.32].

The advantages of a perpetual system are:
- An efficient, meaningful order size.
- Safety stock needed only for the lead time period.
- Relative insensitivity to forecast and parameter changes.
- Less attention for slow-moving items.

The perpetual system has the following weaknesses:
- Reorder points, order quantities, and safety stocks may not be restudied or changed for years.
- Delays in posting transactions can render the system useless for control.
- Data errors can make the system useless.
- Numerous independent orders can result in high transportation and freight costs.

10.5.2. Two-Bin inventory system.

The two-bin system is a simplified version of the perpetual system. The reorder point is determined by visual observation.
When the stock in one bin is depleted, an order is initiated, and demands are then filled from the second bin.

The system can even be used with only one bin. An order can be triggered when the inventory level reaches a physical mark such as a painted line. [C.28] The two-bin system is best suited for items of low value, fairly consistent usage, and short lead time. [D.4]

The most important advantage is reduction in paperwork. Records are not maintained for each withdrawal.

### 10.5.3. Periodic inventory system.

In a periodic inventory system the number of items in storage is reviewed at fixed intervals. A count must be taken of the goods on hand at the start of each period. In the perpetual system an actual count was not required, since inventory records contain receipts, issues, and balances on hand. With the periodic system the quantity to be ordered is not fixed, and the decision maker changes the quantity ordered to reflect changes in the demand rate. Under this system, the review period is fixed; order quantity, the demand rate, and the reorder point is variable; and the lead time can be fixed or variable. [D.29]

The advantages of the perpetual system are:
- A reduction in ordering costs may be possible because items are processed under a single order.
- Shipping costs may be significantly decreased if an order is of a convenient size.
- Because a physical count has taken place, lost or stolen items are not in the system.
10.5.4. Optional replenishment inventory system.

The optional replenishment inventory system, is also referred to as a min-max system. [D.3] Stock levels are reviewed at regular intervals, but orders are not placed until the inventory position has fallen to a predetermined reorder point.

The maximum inventory level is established for each item. If the inventory position is above the reorder point on the review date, no order is placed. If the inventory position is at or below the reorder point on the review date, an order is placed. The order quantity is the maximum inventory level minus the inventory level at review period.

10.5.5. MRP inventory system.

The MRP inventory system is used extensively with planned production. See chapter 8 for more detail. [C.6] The system works well when a) a specific demand for an end product is known in advance; and b) the demand for an item is tied in a predictable fashion to demand for other items.

The subsequent table summarizes the different inventory control system.
### Table 10.1.

**Inventory System Features:**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Perpetual</th>
<th>Two-Bin</th>
<th>Periodic</th>
<th>Optional</th>
<th>MRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order quantity</td>
<td>Fixed</td>
<td>Fixed</td>
<td>Variable</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td>Reorder point</td>
<td>Fixed</td>
<td>Fixed</td>
<td>Variable</td>
<td>Fixed</td>
<td>Variable</td>
</tr>
<tr>
<td>Review period</td>
<td>Variable</td>
<td>Variable</td>
<td>Fixed</td>
<td>Fixed</td>
<td>Fixed</td>
</tr>
<tr>
<td>Demand rate</td>
<td>Fixed/variable</td>
<td>Fixed/variable</td>
<td>Fixed/variable</td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>Lead time</td>
<td>Fixed/variable</td>
<td>Fixed/variable</td>
<td>Fixed/variable</td>
<td>Fixed/variable</td>
<td></td>
</tr>
<tr>
<td>Safety stock</td>
<td>Medium</td>
<td>Medium</td>
<td>Large</td>
<td>Very large</td>
<td>Small/none</td>
</tr>
</tbody>
</table>

10.6. **Time span of estimation.**

The time span of an estimation can be defined into three categories: long term; medium term; and short term.

**Long term.**

The time interval is usually longer than a year. Examples are expansion of the plant, moving of the plant, and a new range of products.
■ Medium term.

The time interval is between six months and a year. Examples are ordering of goods that take long to deliver, usually capital goods or machines, and the preparation of budgets.

■ Short term.

The time interval is between one month and six months. Examples are the estimation of consumer demand, the anticipation of short term trends and the preparation for them. This forecasting term is in the realm of statistical estimation. The previous two, long and medium term, require skill and past experience.

10.7. Statistical methods.

Demand for a product consists of two components: core demand and randomly changing demand. Core demand is consistent over time or changes consistently over time. Core demand can be forecast but only an average demand can be determined for randomly changing demand.

Methods to determine demand are, for example: a) Regression analysis, b) Exponential smoothing, and so on. See the following references for more information [E.1] and [E.2].

10.8. Economic order quantity.

Economic order quantity (EOQ) is used to minimize the total cost to order and to carry a firm's inventory over a specific period. [D.4]
The formula used to determine the economic order quantity (EOQ):

\[
EOQ = \sqrt{\frac{2ARU(CO)}{(CU)(CC)}}
\]

EOQ = Economic order quantity.

ARU = Annual required units.

CO = Cost per order.

CU = Cost per unit.

CC = Carrying cost.

Example:

A computer component manufacturer uses 6000 units of a product each year, the ordering cost is R 30 per order, the cost per unit of the product is R 5, and the carrying cost is 20% of inventory.

ARU = Annual required units = 7600 units.

CO = Cost per order = R 25 per order.

CU = Cost per unit = R 5 per unit.

CC = Carrying cost = 20% of inventory.

\[
ACC = Annual carrying cost = CU.CC(Order quantity/2)
\]

\[
ACC = (5 \cdot 20\% / 2).OQ \quad ACC = OQ/2
\]

Annual cost of ordering = (annual required units) x (cost per order)/(order quantity) ACO = 180000/OQ
Total cost to order and carry = ACC + ACO = OQ/2 + 180000/OQ

The point of intersection of ACC and ACO is found by solving
ACC = ACO : 180000/OQ = OQ/2

which gives OQ = EOQ = 600 units.

Limitations of economic order quantity (EOQ).

a) Inventory carry cost and order cost cannot always be determined accurately. EOQ is an indication, but is not an absolute value.

b) EOQ can lead to uncomfortable order quantities. Rounding its quantity will make it easier to handle.

c) Order on a irregular basis. Something must prompt the use of the EOQ. The higher the value of the stock, the longer the time will be between orders. See Figure 10.2.

![Inventory value against number of orders](image)

Fig. 10.2.
d) The physical store cannot exceed a certain limit before major capital investment is required.

Times when the economic order quantity (EOQ) is not appropriate:

- If price increase is imminent.
- If the producer is going to stop making the product.
- If the demand is not very stable.

10.9. Summary.

This chapter examined the effective management of inventory. Different inventory control systems were discussed, such as perpetual systems, two-bin systems, periodic systems, optional replenishment systems and material requirements planning systems.

The subsequent chapter looks in more detail at Computer Integrated Manufacturing (CIM).
Chapter 11.

Detailed chapter on CIM.

"All the planning in the world will not help an organization realize objectives if plans cannot be implemented."

Ivancevich, Management principles and functions, 4th ed.

11.1. Introduction.

Information systems are the lifeline of production and inventory control operations. These information systems have evolved from stand-alone, batch and punch card type systems to fully integrated and on-line, real-time environments. Today's challenge is to integrate production and inventory control systems across multiple locations. This is necessary to meet ever-increasing demands for improved quality, productivity, and cost constraints.

The purpose of Computer Integrated Manufacturing (CIM) is to transform product ideas and raw materials into high-quality, saleable goods at a minimum cost and in the shortest possible time. Unlike the traditional manufacturing system approach
that splits design and manufacturing functions, CIM tries to integrate these functions. [D.18]

To implement a CIM system we have to take many technologies and blend them, so that the whole is better than the sum of the parts. [C.23]

This chapter addresses the following aspects:
- Building blocks of CIM.
- Management cycle for CIM.
- How to plan and implement different CIM strategies.

### 11.2. Stages toward CIM.

CIM is just one of many concepts currently applied to a manufacturing environments to improve productivity. It is important to relate it to these other concepts in order to assess its application to a given manufacturing environment.

There are four building blocks in CIM. [D.18] The author suggests a further block referred to as Inter-organizational Information Sharing (IOIS). This block is designed to follow CIM, but it can be implemented before or in conjunction with CIM.

These blocks are illustrated in Figure 11.1. The building blocks can also be seen as steps, the sequence of the steps is not significant but it is important, to remember that all the previous information and systems used must be supported and built on, to expand the information processing ability of the organization. The building blocks of CIM are illustrated in Figure 11.1.
Fig. 11.1.

The building blocks or stepping stones are:

Block 1: Traditional Manufacturing.

Block 2: Just-in-time.

Block 3: Islands of automation.

Block 4: Computer integrated manufacturing (CIM).

Block 5: Inter Organization Information Sharing (IOIS).
Each of these stepping stones are discussed in detail in relevant chapters in this study. In order to summarize, each will be referred to briefly.

11.2.1. Block 1: Traditional Manufacturing.

Traditional manufacturing does not refer to the conversion of raw material into a product by primitive means, but to the use of computers in manufacturing and the traditional way they were used.

Traditional manufacturing uses manufacturing resource planning (MRP II) to plan and control production, produces in large lots to minimize the effect of setup costs, and carries buffer inventory that results from large lots and longer times between lots.

Machines are grouped by function, thus parts must travel long distances through the factory to be manufactured. See chapter 8 for more detail.

11.2.2. Block 2: Just-in-time.

Just-in-Time is a commitment to the minimization of inventory. The orientation of a company towards 'zero defect' and the minimization of machine set-up time; the nurturing of a work force that is able to operate under the flexible regime demanded by JIT; and the fostering of a 'total quality' orientation throughout the organisation. [D.6]
Just-in-time manufacturing has the objective of reducing inventories and manufacturing lead time to the lowest level possible.

Unlike traditional manufacturing, it groups together dissimilar machines in U-shaped cells. These cells perform various operations on a workpiece to produce a finished part. The travel distance between machines is greatly reduced, which in turn reduces sophisticated material-handling equipment.

Lot sizes are much smaller because of the concentrated efforts to reduce setup time. This approach has also improved product quality. See chapter 9 for more details.

11.2.3. Block 3: Islands of automation.

Once portions of the production process have been made to flow smoothly by using JIT manufacturing techniques, it is appropriate to automate selectively. These islands of automation technology could be added in the form of robots, CAD, CAM, and other systems and technologies that essentially function independently. These technologies lead to productivity gains in specific areas. [D.18]

Selective use of automation can further reduce lot sizes and inventories, while enhancing product quality and workers' quality of life. In many cases, tedious and even hazardous tasks are automated first; transferring the task from the human to the automated system enhances the workers' quality of life. See chapters 5, 6 & 7 for more details.
Reasons for islands of automation [D.33].

a) No proven and standardized CIM concepts have as yet been offered in the marketplace.

b) The financial cost of purchase, individual development and implementation measures is high.

c) There is a lack of modular concepts by means of which the investment cost can be spread over a period of time, and experience of the new technology can be gained.

d) Reluctance on the part of the users faced with complex problems presented by far-reaching and comprehensive changes in existing organisational structures, and with considerable uncertainty relating to planning.

e) A lack of know-how concerning the selection, adaption and introduction of integrated solutions on the part of the potential system user.

f) Departmental egotism and acceptance problems.

The following are a short list of the major disadvantages of automated islands.

Disadvantages of islands of automation [C.33]:

a) Multiple storage of identical sets of basic data.

b) Manual multiple entry of identical data.

c) Costly and non-simultaneous updating of the sets of data, with the result that the sets are frequently not identical.
d) A lack of clarity and lengthy throughput times when processing jobs.

11.2.4. Block 4: Computer Integrated Manufacturing (CIM).

CIM links islands of automation. Prior to this stage engineering, and planning and control systems were essentially separate. Information technology unites the two.

The ideal lot size of one can be achieved because the part can be manufactured and controlled by computer. The time to design and manufacture the product is reduced dramatically, through the integration of all components of the design, manufacturing, and planning and control process. The risk of incorrect data transfer between these systems is reduced because people, who are prone to error, are not used. Instead, communication cables and share databases are used.

The links between islands of automation follow two basic principal ideas [C.33]:

- Creating an uninterrupted digital information flow between all computer assisted technical administrative departments of a plant.
- Avoiding multi-programming and multi-keeping of the same data in the memories of the computer systems in different departments.

CIM means computer integrated manufacturing. The goal is to tie all the various computers, and other programmable devices found in the factory into one integrated network wherever it is operationally advantageous and profitable to do so. [C.21]
Because CIM is an all-encompassing concept, a wide range of functions is covered by CIM systems and subsystems. The elements of CIM can be classified as engineering technology, production technology, and information technology.

Engineering technology include:

- Computer-Aided Design (CAD).
- Computer-Aided Engineering (CAE).
- Computer-Aided Manufacturing (CAM).
- Group technology.
- Production technology
- Information technology.

Aspects not addressed in previous chapters are Group technology, Production technology and Information technology and will now be briefly discussed.

Group technology.

The group technology subsystem provides a classification scheme, or taxonomy for parts and tools. This taxonomy supports process planning, retrieval of design stored in the database, and tool selection.

Items classified in this manner include both purchased and manufactured parts, as well as cutting tools, jigs and fixtures.
The parts are classified by their physical attributes, or their manufacturing attributes. Physical attributes by which parts can be classified are length, width, thickness, and tolerance. Manufacturing attributes by which parts can be classified are drill, mill and tap specifications.

Once a large subset of parts is coded in this manner, designers of new parts and tools can quickly determine whether a similar part or tool already exists in the data base. If a similar part exists it can be modified to make a new part or can be copied without redoing it. This will reduce design cost considerably.

Group technology is based on the premise that the number of substantially different processes is relatively small in comparison to the number of existing items. [D.18] If this is not the case the company has enormous diversified products. The characteristics of Group technology are graphically illustrated in Figure 11.2.

Typical characteristics for Group Technology Analysis.

<table>
<thead>
<tr>
<th>Design</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Machine tools</td>
</tr>
<tr>
<td>Material</td>
<td>Operations</td>
</tr>
<tr>
<td>Major dimension</td>
<td>Operation sequence</td>
</tr>
<tr>
<td>Weight</td>
<td>Tooling</td>
</tr>
<tr>
<td>Width</td>
<td>Tolerances</td>
</tr>
<tr>
<td>Diameter</td>
<td>Surface finish</td>
</tr>
<tr>
<td>Function</td>
<td>Inspection requirements</td>
</tr>
</tbody>
</table>

Fig. 11.2.
Production technology

This includes a wide range of hardware and software: process control, inspection and quality control devices, robots, computer numeric control (CNC) machines, automated storage and handling.

Information technology.

This include computer hardware and software, data base management systems, communications, information centers, artificial intelligence, decision support, and simulation.

11.2.5. Block 5: Inter Organizational Information Sharing.

The last stage according to the author is the linking of information systems of suppliers, with manufacturers and distributors. This will enhance user satisfaction, reduce administration costs due to the reduction in paper flow between companies in the distribution chain, and will reduce lead time.

The objective here is the vertical integration of information systems, even though there are different companies in the vertical chain. (see Figure 11.3.) The vertical integration of information comes from marketing literature [D.20], discussions between chain members centered on the positioning of certain products, and not only on pricing of the product.

A product, line of products, or a company is positioned in the eyes and minds of buyers. This positioning of a firm's offering is influenced by the marketing actions of a company as well as
by the marketing efforts of competitors. A marketing action is the combination of the product, channel of distribution, price, and promotion strategies selected by management to position a firm against its key competitors in meeting the needs and wants of the market. [D.20]

The discussions are conceptual and can be expanded to include the effective transfer of information between chain members.

**Inter Organisation Information Sharing (IOIS)**

- **Supplier**
- **Manufacturer**
- **Distributor**

**Standard Information Requirements:**
- Actual and expected demand.
- How expected demand was calculated.
- Any problems with supply.
- Future price increases.
- Linked re-order facility.

Fig. 11.3.
The current trend to "open systems" will help companies to create standard interfaces that will link the supplier to the manufacturer to the distributor. This can only be achieved if discussions between the companies in the chain centres less on price and more on co-operation.

The information links between the companies in the chain must be standard. Modules that provide standard services to its suppliers or distributor without compromising on data integrity, data loss or the interception of data must be secured. In Figure 11.3, typical chain members are illustrated as well as information that can be transferred between chain members.

Types of information that can be part of the standard services for the companies in the chain can be: estimated demand for the company's product, how the estimation was made, how long it takes to manufacture the product, the fastest route between the people in the chain, re-ordering facility, and so on. Chapter 13 discusses IOIS in more detail.

11.3. CIM framework.

The actual application of the CIM concept varies from environment to environment. The following represents a framework for a typical CIM system.

Pyramid concepts.

In the ideal CIM environment, the activities of the manufacturing enterprise are performed by several organisational entities and coordinated through various levels of management.
In Figure 11.4, the five levels of activity that CIM typically addresses can be identified. These five levels form the CIM hierarchy.

![CIM pyramid]

Source [D.18]

Fig. 11.4.

11.3.1. Plant level.

The Plant level corresponds to those organizational units responsible for managing a company's overall operations. These activities include those performed by the plant manager, accounting, and long-range planning.
11.3.2. Center level.

The Center level in manufacturing refers to major portions of the plant such as a line or department. Activities supported at this level include daily scheduling, and overall monitoring and control of the manufacturing cells.

11.3.3. Manufacturing cell.

A Manufacturing cell is a group of machines organized to work together and managed as a unit in matching manufacturing capacities to production requirements.

11.3.4. Manufacturing station.

A Manufacturing station, or workstation, is the lowest level at which the manufacturing center operates. Typically, the workstation consists of one or more machines and material-handling equipment within a manufacturing cell.

11.3.5. Manufacturing process.

A Manufacturing process is an operation performed on material at a workstation. Examples include milling, drilling, cutting, and assembly.

A successful CIM system must support effective communication among the various levels of the CIM hierarchy.
11.4. CIM Plan.

The plan should carry out short term goals/objectives and provide the building blocks necessary to leverage technology as it grows and evolves.

The architecture which develops should not be proprietary in nature and should empower the user with what is needed to modify the system. Short term goals should address the goals of time saving, employee resource allocation, and should have strong quality enhancing mechanisms. Quality control should concentrate on the prevention of defects and errors during each stage of the product cycle. The system should provide the necessary feedback to close the loop. [C.29]

The long term strategy will address how the system would automatically compensate for changes in production.

It is important for the automation plan to exist before one begins to go shopping for products. If one's plan is concise and identifies the specific control and data management requirements, the equipment selection process will be easier.

One must also consider how it will integrate with your operators, engineering groups, maintenance personnel, design department, quality control group and distribution.
A typical architecture can be approached by focussing on several functional areas:

- **Raw material handling.**
  This would include the automatic receipt of raw and bulk material, usage prioritization, storage capacities as well as pre-processing of materials.

- **Product processing.**
  This area has traditionally been a strong area of focus for companies wishing to automate. Product quality, upstream/downstream coordination, scrap rate saving, time control, and so on are all excellent areas to concentrate on initially.

- **Warehousing/distribution centers.**
  The areas to focus on here are coordination, loading scheduling, truck location scheduling and automatic receipt orders update.

- **Utility and building services.**
  With the cost of energy increasing one can easily see how, by monitoring energy usage within areas of production, excessive costs can be identified and reduced. The same will be true for water, heating, ventilation, air and other utilities the manufacturing process might use.
11.5. Management Cycle for CIM.

[Page 186]

Stage 1 INTRODUCTION.

a) Concepts of a CIM Business strategy.

b) Managers' roles.

c) Creating interest in CIM.

d) Developing the climate for a CIM-initiative.

Stage 2 PREPARATION.

a) Forming a study team for CIM.

b) CIM opportunity candidates.

c) Conceptualizing. Introduction to the CIM way of operating.

Stage 3 PROGRAM PLAN.

a) Proposal development.

b) Selling proposal.

c) Programme commitment.

Stage 4 IMPLEMENTATION.

a) Managing the implementation

b) Measuring and evaluating results.
c) Moving to the next opportunity.

d) Sharing experience and expertise.

How do we achieve and sustain advantage over our competitors [C.25]?

Phase 1: Short term productivity improvements.

Phase 2: Development of a manufacturing and CIM strategy.

See section 11.9 for more details. To assist in understanding the characteristics of both the product and the marketplace it is useful to use the parameters of:

- Complexity.
- Uncertainty.

The Puttick complexity/uncertainty grid

```

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Capital equipment</td>
<td>Fashion Jobbing</td>
</tr>
<tr>
<td>Low</td>
<td>Durables</td>
<td>Commodities</td>
</tr>
</tbody>
</table>
```

Source [C.25]

Fig. 11.5.
The 'Hot buttons' of competitive advantage.

### Fig. 11.6.

**Phase 3: Create an effective organization.**

Chapter 14 has more detailed information on the restructuring of the organization.

**Phase 4: Implementation of CIM.**

Section 11.8 discusses this.

The following aspects of one's systems must be addressed for integration [C.29]:

- **Conceptual design.** During this stage the automation team should establish specifications and strategies for the creation of the integration architecture.
Concept feasibility and justification. The automation team should be able to demonstrate how the system will perform and assist in justifying the value of the architecture.

Functional and operational design. Develop a complete design of the system. Make sure the design meets the requirements.

Gantt or Pert Charts. Either Gantt or Pert charts should be generated for the project. This will help manage the project and assist in assessing the progress.

Engineering submittals. Decide what hardware should be used. The specific components should be reviewed to determine whether they meet with the criteria outlined.

Design verification. Revise design and make final design.

Engineering and software. Start developing the system.

Factory acceptance testing. Evaluate the prototype of the system against needs that started the development of the system.

Installation coordination. Start to install the system in the factory.

Start-up/debugging/calibration. Make sure all links work and that there are no bugs in the software.

Training and documentation service. This process can be started during the final design phase. The earlier it starts the greater the chance that the system will succeed.
Service and Maintenance. Ongoing training of new personnel and retraining of "old hands" to refine their skills and to make them aware of new functions. Constant maintenance of system to improve performance and to enhance functions.

11.6. Guidelines for the implementation of CIM.

The following are guidelines which can be used to implement CIM. [C.10]

1) Do not start the trip without a roadmap.

You must have long-term objectives and these should be supported by long range plans.

2) Remember that what is tailor-made fits best.

For new products, design the product and the process simultaneously.

3) Set your sights high — make zero defects and a lot size of one your goal.

Raise your sights and make quality a competitive weapon. Seek the flexibility to give your factory machines a chance to outlive the product it is producing.

4) Make your system great, then automate.

Identify problem areas in current system, rectify these problems and then automate. Automation does not resolve problems but only speeds up the processing time; thus errors in the current system will become apparent faster and more intensely.
5) Only automate things that add value.

Identify costs that add value and those that add cost. Get rid of things that add cost without adding value, and automate things that add value. This will reduce cost.

6) Do not focus only on reducing direct labour.

Direct labour generally accounts for less than 10 per cent of the sales for most products. [C.10] The company can achieve larger savings by reducing indirect labour, trimming inventory, lowering the cost of quality, and being first in the market.

7) Plan from the top down.

Lower levels of management lack the vision to plan an effective strategy for the company that will affect the way in which the company’s work force addresses problems. This CIM strategy will lead to a cultural change, top management approval is the only way this will be achieved.

8) Implement from the bottom up.

A plan must be implemented. As soon as top management starts the ball rolling, the plan (strategy) must be simple yet comprehensive enough for the low levels of management to understand it. Lower levels keep the ball rolling, they must identify future applications and problems. This will help to create a atmosphere of innovation and creative thinking.
9) **Don't be too anxious.**

CIM requires cultural change in the company. Changes of this nature take time, usually involve a lot of frustration and perhaps even failure has to be withstood in order to succeed.

10) **Do not implement without training people.**

CIM requires an innovative and highly productive organisation. Each employee is a critical link in the system. Everyone must follow the same plan and must know exactly what his part is in the whole. These people must be properly trained, motivated, and rewarded.

11) **Principles that have proven to be successful include [C.25]:**

   a) Focusing resources on defined market niches.

   b) Identifying the critical competence of the business.

   c) Simplifying whenever possible, rather than introducing complexity to cope with sophistication.

   d) Introducing a culture of continuous improvement through a never-ending sequence of progressive steps.

   e) Solving all problems at source.

**11.7. CIM strategies.**

For CIM to be successful, commitment is required from the entire work-force, from the director to the sweepers.
A good manufacturing strategy identifies what a company must do well in order to survive and prosper. It also highlights which design and manufacturing processes need to be improved and in which order. [C.34]

In evolving a strategy for CIM there appear to be two possible routes [C.21]:

- The technocentric approach, which installs islands of automation based on advanced technology and gradually works towards linking these into a fully integrated continent - the factory of the future. Here problems are perceived as principally composed of financial and technological elements and the dominant belief is that if enough resources are thrown at the problem it will be solved. To solve the problem, throw more “system” at it— develop more complex software. This is unnecessary complex and unpractical.

- The organocentric approach, in which the process of technological innovation follows that of organisational adaption. The pattern follows roughly the prescription ‘simplify, integrate, computerintegrate’ and implies an incremental approach based on low-risk, high-return organisational changes building up gradually to higher-risk technological changes such as CAD/CAM and CIM.

Automation Strategies.

The following automation strategies are proposed by Groover. [C.30]
1) Specialization of operations.

The first strategy involves the use of special-purpose equipment designed to perform one operation with the greatest possible efficiency.

2) Combined operations.

Production occurs as a sequence of operations. Complex parts may require hundreds of processing steps. The strategy aims at reducing the number of distinct production machines or workstations. Material handling is also reduced.

3) Simultaneous operations.

Performing two or more processing operations simultaneously on the same workpart, thus reducing total processing time.

4) Integration of operations.

Link several workstations into a single integrated mechanism using automated work handling devices, like conveyer belts, to transfer parts between stations.

5) Increased flexibility.

This strategy attempts to achieve maximum utilization of equipment by using the same equipment for a variety of products. The prime objectives are to reduce setup time and programming time for the production machines.
6) **Improved material handling and storage.**

A great opportunity for reducing nonproductive time exists in the use of automated material handling and storage systems. Reduces work-in-process and shortens manufacturing lead time.

7) **On-line Inspection.**

Quality inspection is traditionally performed after the work, which means that any poor-quality product has already been produced. Inspecting the quality as the product is made will help to reduce scrap costs and will improve the quality of end products.

8) **Process control and optimization.**

This includes a wide range of control schemes intended to operate the individual processes and associated equipment more efficiently. By means of this strategy, the individual process times can be reduced and product quality improved.

9) **Plant operations control.**

This strategy is concerned with control at the plant level. It attempts to manage and coordinate the operations in the plant more efficiently. Its implementation usually involves a high level of computer networking within the factory.

10) **Computer Integrated manufacturing (CIM).**

Taking the previous strategy one step further, we have the integration of factory operations with engineering design and many
of the other business functions of the firm. CIM involves extensive use of computer applications, computer data bases, and computer networking in the company.

11) Inter Organizational Information Sharing (IOIS).

As already mentioned by the author, IOIS is the integration of vertical channel members' information resources. Pre-defined and secure information interface must exist between the supplier of raw material, the manufacturer and the distributor.

11.8. Summary.

The question arises as to why CIM is moving so slowly [C.25]. The reason is that traditional company organisations and culture are often ill-suited to adopt CIM. This aspect is addressed in chapter 14.

Thomas Gunn, in Manufacturing for competitive advantage: becoming a world class manufacturer, states that most companies lack three important elements that prevent them from becoming world class manufacturers. "These are vision, senior management leadership and a process for translating the vision into reality." [C.34]

The following chapter will examine MAP.

-oOo-
Chapter 12.

The Manufacturing Automation Protocol.

"We are drowning in information but starved for knowledge."

Computer Mail, 31 March 1989

12.1. Introduction.

This chapter looks at the Manufacturing Automation Protocol — MAP. MAP is a set of standard communication services for factory automation.

COMPUTER INTEGRATED MANUFACTURING (CIM) has traditionally meant equipment from different vendors residing in isolated "islands of automation" because the proprietary components used by the various vendors could not communicate with each other. In many cases, they could not even share the same cable. As a result, cabling was a nightmare, as was the effort of porting applications across different vendors' equipment. [C.31]

Training for these different networks was difficult to provide for users and support staff, and the cost of the various kinds of test equipment to keep it all running was also high. Data
throughput was typically low, and centralized management and control of the network became virtually impossible. [C.43]

The alternative to this collection of incompatible technology was to use only equipment from a single vendor, thus locking the user into a future dominated by that vendor, regardless of price-performance or functionality benefits provided by other equipment vendors. This was really no alternative at all, since no single vendor could meet all the equipment requirements on the factory floor.

The MAP services, and the data communication protocols that provide them, are derived from the Open Systems Interconnection (OSI) model as defined by the International Organization for Standardization (ISO). [C.30]

12.2. History of MAP.

Hewlett Packard's (HP's) involvement in the MAP program began in 1984 with MAP 1.0. An implementation of MAP 1.0 was done on the HP 1000 computer system and demonstrated at the National Computer Conference of 1984. [C.43] The MAP Users Group was created that same year and Hewlett Packard (HP) was a founding member.

In 1985, HP demonstrated MAP 2.1 at Autofact, a factory automation forum. [C.26] Also in that year, HP joined the European MAP Users Group and completed the first functional installation of a MAP system at General Motors Corporation in Detroit, Michigan. In 1987 HP introduced MAP 2.1 on the HP 9000 Series 800 computer system. And in 1989 HP released the
current version of MAP 3.0 for volume shipments on the HP 9000 Series 800 computers. [C.30]

12.3. Services provided by MAP 3.0.

Three OSI services are currently provided in HP MAP 3.0: the ISO File Transfer, Access, and Management (FTAM) services, the ISO Manufacturing Message Specification (MMS), and the ISO/CCITT X.500 directory services. [C.26] The HP FTAM and MMS products are called HP MAP 3.0, FTANV800, and MMS/800 respectively. Only the services provided by FTAM and NMS can be directly accessed by the user. The X.500 directory services are accessed indirectly through FTAM and MMS.

FTAM provides users with the ability to access and manage files on remote systems in an internationally standardized way. The programmatic interface includes subroutines that read and write individual records in files and subroutines to delete files and copy files between systems or on the same system. [C.43]

MMS is designed for use with manufacturing devices such as robots. Various control and monitoring operations are provided. For example, there are subroutines for reading and setting variables such as counters and alarm condition thresholds. A bulk data transfer facility (e.g., for downloading a program) is also provided. [C.26]

12.4. Architectural Overview

In HP's MAP 3.0 product, the application services are implemented in software residing on the HP 9000 Series 800 computer system. The Application Control Service Element
(ACSE) protocol and most of the OSI lower layer functions (from the presentation layer to the IEEE 802.4 physical layer protocols) are implemented on the HP OSI Express card, which is a microprocessor-based I/O card that plugs into the backplane of the host computer. [C.11] & [C.43]
Figure 12.1. shows the overall architecture of HP's MAP 3.0 product. User Application Programs are programs written by end users or independent software vendors who may use FTAM for file access and/or MMS for monitoring factory floor devices. These applications use the MAP application program interfaces to access the HP NM 3.0 services.

The application program interfaces are libraries that are linked into the user's program to enable communication with the various service provider processes.

Service Provider Process (SPP). The service provider processes contain the modules that provide the KUP services (FTAM and MMS) and the asynchronous operation capabilities specified by the MAP protocol.

FTAM Responder. The FTAM responder is an FTAM process that handles requests for file manipulation activities on the local machine. Typically these requests are initiated by remote users. If a local user wants to access some remote file, first the local FTAM SPP is used. When the request reaches the remote machine, the FTAM responder on that machine handles the request.

Upper Layer Architecture Modules. The upper layer architecture modules provide connection management and syntax transformation services to the SPPs and the FTAM responder. The upper layer architecture modules also provide a platform for the development of OSI services.

MAP Kernel Modules. The MAP kernel modules, which are software modules embedded in the HP-UX kernel, are respon-
sible for communicating with the HP OSI Express card and hence to other systems or devices on the network.

**Configuration Database.** This data base contains information that is pertinent to the local system, such as the default levels of tracing and logging and the addresses of the applications on the local host.

**Configuration User Interface.** This user interface allows users to enter data into the local configuration data base. It can also be used to update information on a (possibly remote) directory system.

**Directory Services.** The directory services in MAP are based on the OSI X.500 standard. This software provides facilities for determining the locations of applications and resources in a network.

**Directory Information Base (DIB).** The DIB is the data base that implements the structure of the X.500 directory. It contains the names, addresses, and other information required to find the locations of remote systems and/or applications. The DIB may reside on the local system or a remote system.

**Start/Stop/Control User Interface.** This interface allows users to start and stop networking, and to monitor and control the level of tracing and logging. Tracing and logging information is used to facilitate troubleshooting the network.

**Card Management Software.** This software is invoked by the start/stop/control user interface to download the HP OSI Express card’s software, and to control the card’s operations.
Tracing/Logging Subsystem. This subsystem is responsible for taking the traces and event logs from all of the other HP MAP 3.0 software modules. Each module in the system has a connection to the tracing/logging subsystem. This uniform tracing and logging scheme was a MAP product from the outset to ensure consistent tracing and logging policies and consistent formatting of the tracing and logging information.

12.5. Conclusion

The result of many years of manufacturing and networking experience, MAP is an intervendor program that addresses the problems that have plagued factory automation in the past. HP's MAP 3.0 product combines international standard services and protocols with the multivendor MAP programmatic interface.

Screen-based utilities simplify configuration and verification. A uniform tracing/logging policy and uniformly formatted output facilitate diagnostic and troubleshooting tasks. The MAP programmatic interface provides enforcement of configured limits, and allows asynchronous and high-level operations.

The subsequent chapter will discuss Inter Organization Information Sharing – IOIS.

-oOo-
Inter Organization Information Sharing (IOIS)

"The reasonable man adapts himself to the world, the unreasonable man adapts the world to him. All progress depends on the unreasonable man."

George Bernard Shaw.

13.1. Introduction.

The trend in the literature is that CIM is the ultimate information goal. [C.30], [C.23], [C.21], [C.33]. The question arises whether this is true; if not, then what is the goal after CIM.

CIM does not address all the organization's information needs. None of the external information needs are addressed. CIM is internally focussed. The objective of CIM is effective management of internal information sources.

What about external information sources?

Organizations that are internally focussed lack practical and innovative concepts and ideas. Customers needs and wants are
often neglected because of outdated perceptions of what the customer wants.

By tapping the neglected external information sources the organization can gain a competitive advantage, the reason being the organization knows exactly what its customers' needs and wants are, and are in touch with market trends and new innovations.

A way to start tapping this external information source is by obtaining information from one's suppliers and distributors. If this is successful then the external focussed information system can examine other sources such as government, overseas support and links to inventors.

This study proposes that an organization can gain a competitive advantage by establishing information links to its suppliers and distributors. These links are also referred to as vertical chains or vertical channels.

In the past discussions between chain members centred around price; currently the discussions centres around the positioning of the product. [D.20] In the future discussions will center around information exchange.

A product, line of products, or a company is positioned in the eyes and minds of buyers. This positioning of a firm's offering is influenced by the marketing actions of a company as well as by the marketing efforts of competitors. A marketing action is the combination of the product, channel of distribution, price, and promotion strategies selected by management to
position a firm against its key competitors in meeting the needs and wants of the market. [D.20]

We propose Inter Organisation Information Sharing or IOIS. The objective here is the vertical integration of information systems, even though there are different companies in the vertical chain. See Figure 13.1.

The discussions are conceptual and can be expanded to include the effective transfer of information between chain members.

The current trend to “open systems” will help the companies to create standard interfaces that will link the supplier, manufacture and the distributor. This can only be achieved if discussions between the companies in the chain centres less around price and more on co-operation.

The information links between companies in the chain must be standard secure modules that provide standard services to suppliers or distributor without compromising on data integrity, data loss or the interception of data.

In Figure 13.1, typical chain members are illustrated as well as information that can be transferred between chain members.
13.2. Definition of Inter Organisation Information Sharing.

*Inter Organisation Information Sharing* or IOIS can be defined as the exchange or sharing of information, data and/or information services by vertical chain members.

A vertical chain is in its simplest form an organisation that supply or receive goods from another organisation. Simple chain configuration can, for example, be a manufacturer and a distributor, or a manufacturer and a supplier, or a manufacturer and his supplier and distributor.
Information, data and/or information services as mentioned in the definition, include unprocessed information, processed information, software and hardware. Unprocessed information is sometimes also referred to as data, and can be seen as the "raw material" of the information.

Processed information is information that has been refined to varying degrees. This type of information is usually produced by data bases, expert systems, application software, and so on.

Software and hardware in the definition refer to all types of software and hardware.

Inter Organisation Information Sharing (IOIS) is the sharing of all the information resources by companies vertically associated with one another. The only limitation is the extent to which all the chain members can agree on the type of information to be shared.

The type of information that can be shared between channel members must be part of the discussions between the chain members. The subsequent section will provide some guidelines on what types of information can be shared.

13.3. Types of information to be shared.

When considering the information to be shared the following must be examined: the relevance of the information, the costs of the information, how sensitive the information is, how much it will cost to protect this sensitive information, how much damage this information will cause if it leaks out, and
whether the risk taken is less than the advantages gained from the legal use of this information.

**Types of information:**

- Actual and expected demand.
- How expected demand was calculated.
- Any current and future supply problems.
- Current and future prices.
- Linked re-order facility.
- Information on the positioning of the product:
  - Price
  - Place
  - Promotion
  - Product
- The product's position in the product life cycle.
- Anticipated macro economic and political changes and how they will affect the future supply and demand of the product.

After discussions have finalized the types of information to be shared, the organizations involved must decide who is responsible for the implementation of the project and how costs are to be paid for. From this point it is like implementing any information system.

**13.4. Methods to apply IOIS.**

There is a number of ways of applying Inter Organization Information Sharing (IOIS).
They are:

- Use an expert system as an intelligent front end.
- Use a dedicated expert system on a remote site.
- Use a curtailed database.
- Use "intelligent" electronic mail.
- Use a blackboard type system.
- Limited functions or commands to corporate data base.
- Access to a Standard Secure User Interface.
- Floppy Post.

13.4.1. Use an expert system as an intelligent front end.

As can be seen in Figure 13.2., the expert system is used as an interface to the corporate data base. The corporate data base is the manufacturer's data base.

**Expert system as intelligent Front End.**

![Diagram of Expert system as intelligent Front End.](image)

Fig. 13.2.
The link between the data base and the expert system must be secure. The data base must be protected against any malicious attacks. The expert system must enforce limited access and rights.

13.4.2. Use a dedicated expert system on a remote site.

Place a dedicated expert system in the supplier's or distributor's office.

![Dedicated Expert System on remote site.](image)

Fig. 13.3.

This method can be used if there is trust between the vertical channel members, usually in industries where there are few participants and the chain is fairly short.

The knowledge base must be secure. All the routes through the knowledge base must be tested to prevent sensitive data from slipping out.

13.4.3. Use a curtailed data base.

Use a secure data base which is only a very small brother of the corporate data base. The connection between the two data
bases does not need to be permanent. The curtailed data base can be updated on a regular basis. Prevent the curtailed data base from having write rights to the corporate data base and limit its read rights.

13.4.4. Use "intelligent" electronic mail.

An electronic mail facility can be used to exchange intelligent reports. These reports are generated by an expert system linked to a data base.
13.4.5. Use a blackboard type system.

This blackboard can either be on a central computer or distributed across several computers.

![Central Black Board Diagram](image)

![Distributed Black Board System Diagram](image)

Fig. 13.6.

Fig. 13.7.
Types of information that can be on this black board type system are:

- Screened data or information.
- Reports.
- Secure and tested software to access the corporate database.
- Pre-determined and standard check boxes.

13.4.6. Limited functions or commands to data base.

Allocate certain rights to the chain members just like internal users. The chain members will have certain rights which will give them access to the database. The systems administrator can terminate these rights. Figure 13.7. illustrates this.

**Limited access to Data Base.**

![Limited access to Data Base diagram]

Fig. 13.8.

Access to a standard menu of options. This menu will supply information. The information composition will be determined by discussions between chain members.

![Inter Organisation Information Sharing (IOIS)](image)

SI = Standard Secure Information Interface

Fig. 13.9.

No other information or functions can be defined without prior consultation. Thus only information that appears on the menu will be supplied.

13.4.8. Floppy Post.

Very primitive but can be very effective. Send a floppy or data storage medium to chain members. This floppy can contain information as mentioned previously.
13.5. Critical evaluation of IOIS.

The main advantages and disadvantages of IOIS are highlighted here.

Advantages of IOIS.
- Enhances user satisfaction.
- Reduces administration costs.
- Reduces paper flow between companies.
- Reduces lead time.
- Faster response to market changes.
- More accurate forecasting.

Disadvantages of IOIS.
- Success of this stage depends on co-operation between the channel members.
- Risk of malicious attack.
- Long term to implement and reach an agreement.
- What about legal aspects?


This security system can be used to encapsulate the chosen method of applying IOIS.

Normal validation principles, such as a password and user id. linked to a data base of access rights, can be applied.

SmartCard systems or other forms of docketing can be used to improve security and may contain data encryption and decryption keys.
13.7. Summary.

This chapter proposed a concept called Inter Organisation Information Sharing or IOIS. The objective here is the vertical integration of information systems across organisational boundaries.

The subsequent chapter examines the management of technological change.

-oOo-
Chapter 14.

Management of Technological Change.

"Change takes place no matter what deters it ... There must be measured, laborious preparation for change to avoid chaos."

Plato

14.1. Introduction.

A critical issue for most organizations has become the rate and intensity of environmentally-driven change and how the organization adapts to it. This chapter examines the impact of change on the organization.

Information systems affects the organization as a whole from the individual worker right through to the structure and culture. The effect of the impact of information systems must be addressed by top management and the organization as a whole. This chapter examines relevant ways and means to address this problem.

The reason why the problem of organizational change has become so important is due to two main factors. Firstly, environmental change seems to have become continuous and ac-
celerating. Secondly, due to their higher education and expectations people can no longer be ordered to adapt.

One way of looking at change is to divide it into 'content' and 'process'. 'Content' refers to the most tangible elements which are to be changed, the 'what' of a change programme — systems, machinery, responsibilities and structure. 'Process' is the 'how', the way in which the actual change will be carried out. [F.20]

Due to the factors mentioned above it is very important to examine the impact of information technology and especially CIM on the organization.

14.2. Resistance to change.

People resist change. Every manager knows that. Many managers also resist change. The fact is that what people resist is not change itself, but the way it is introduced. The 'content' may be acceptable but if the 'process' is mishandled, resistance may creep in.

The reasons why people resist change can be classified into three groups — rational, emotional, and political. [F.20]

14.2.1. Rational.

- They believe the change to be wrong, the time to be wrong or the methods to be inappropriate.
- They don't feel that their views are taken into account.
- They have seen other management decisions fail and view this as just one more that will fail. They don't feel that
management has the ability to implement the change successfully.

- They see no benefits in it for themselves.

14.2.2. Emotional.

- Change means criticism of the way things are done at the moment. They may even be responsible for building up current systems.

- There is a lack of trust towards management and they expect a hidden agenda behind the change, such as for instance reducing staff.

- They are afraid of not being able to cope with the changes, of looking stupid, or failing in the new environment.

14.2.3. Political.

- They think they will lose power, status, authority or freedom.

- They believe the skills they have will become less important, that they may even lose their jobs.

- There is peer pressure from colleagues to resist.

The resistance to change can come from a range of rational and irrational sources and is often rooted deep in people's feelings and beliefs. It is therefore critical that leaders of an organization invest time and energy in the process of change.

There are steps which top management can follow to make the transition swift and without any internal conflict.
14.3. Steps towards the change process.

There are four basic steps in the change process: 1) define the desired end state; 2) define the current state; 3) plan change; and 4) the choice of a transition manager. [F.20]

14.3.1. Defining the desired end state.

A useful early step in the change process is to try and make a detailed description of the desired end state and to communicate this to all the people who will be affected.

The benefits are:

- The organization has a clear target to aim for.
- People's anxieties are reduced because they can visualize what will happen, and thus feel less uncertain.
- Working towards a shared vision is a constructive activity, one that generates optimism.
- People are given something to build on and can begin to see roles for themselves in both the change process and the desired end state.

14.3.2. Defining the current state.

As part of making people aware of the need for change, management may need to provide a realistic assessment of how things currently stand. This may include a description of the strengths and weaknesses of existing methods and the desired state.
14.3.3. Planning change.

A comprehensive plan will try to address how change will be achieved at three levels [F.20] :

a) Formal technical systems — what changes will there be in equipment, systems, technology and operating procedures?

b) Formal structures — who will be responsible for what, what will be their official position, who will report to whom, and what will be the change in status of rewards?

c) Informal structures — where is the main power of interest groups and how will they be affected?

A key part of the plan will be an identification of:

- Who will be the winners in the process and how they can be used to help implement the change.
- Who will be the losers, how they will resist the changes, and what they can be offered to lower their opposition.
- Who might, mistakenly, believe they will be a loser because they have received inadequate information, how communication can be improved to ensure they do not misunderstand the situation and oppose the change.

14.3.4. Choice of a transition manager.

The importance of this position tends to be underestimated and the choice of the wrong person can sink the whole programme.

It is generally accepted that a transition manager should have three main characteristics [F.20] :
a) The authority to drive through the change if discussion and negotiation fail to overcome resistance.

b) The power to obtain sufficient resources to carry out the change when there are conflicting demands on resources.

c) Considerable interpersonal skills including the ability to negotiate, to obtain respect, to generate enthusiasm, and to sell ideas.

In the following section some guidelines are stipulated.

14.4. Guidelines for the management of technological change.

Look out for technologically driven change, and make sure the change is problem oriented. Technology has little use if it does not address a problem or if the technology is not used for the specific problem area it is designed for. [F.15]

Make sure the changes address a company problem, and that management understands the problem and the impact of the technology on the organisation.

Identify the wants and needs for the new technology in the company now and in the future. Information technology is flexible and has a wide variety of possible applications. It is of the utmost importance for the company to have an information strategy. This will not only give direction to the information staff, but will help management to measure the performance of the information project. In order to know what road to follow you must know where you want to go.
Management must identify specific problems areas where information systems can be used and must set clear, reachable objectives. These objectives will help to determine whether the system is successful or not. This information can be used in future projects to reduce the risk of failure as well as the costs.

14.5. Reasons why information technology decisions must be taken at board level.

The following reasons explain why information technology decisions must be taken at board (Board of directors) level.

The strategic level or top management has the ability to take strategic decisions and make company-wide change.

The time has come for strategic applications of information technology. These strategic applications help to reach company objectives, which are set at strategic level. The methods to reach these objectives must be on strategic level as well.

The implementation of information technology usually occurs in conjunction with major internal change in the company. The restructuring of the company and the management of change is normal practice for top management.

If the information technology is not managed it may lead to a undetected impact on the company that may influence its effectiveness. This may cause internal conflict within the company.

Information technology influences the company as a whole from the individual worker right through the structure.
Because the implementation of CIM (Computer integrated manufacturing) and IOIS (Interorganizational information sharing) is long term in nature, there must be intermediate steps to prepare the organization for these technologies. One of the intermediate steps is the restructuring of the internal structure of the organization.


The structure of a corporation is often defined in terms of communication, authority and work flow. It is the formal arrangement of roles and relationships of people so that the work is directed toward meeting the goals and accomplishing the mission of the corporation. [F.17]

The following questions need to be answered honestly to see if there is a misalignment in the structure of the company [F.20]:

a) What business are we in?

b) How are we going to compete in that business?

c) What are the factors which are critical to our success in that business?

d) What is our organization's main goal?

e) What are the goals of each major department?

f) Do the departmental goals support or hinder the organization’s goal?

g) What are the main measures used for evaluating each department’s performance?
h) Do these help or prevent the department from contributing to the organization's goals?

During the industrial revolution some organizations had major structural change while others did not change as much. Information technology will have the same influence on the organization.

Remember that not just one factor influences the organization, but a combination of several factors. It is not easy to take a single factor like information technology and determine its impact on the organization.

The author will attempt to isolate the impact of information technology on the structure of the organization.

The personnel in an organization have their own functions, which can be divided into five basic groups. Because of these five basic groups the organization can be divided into five basic parts according to Henry Mintzberg. [F.16] These basic parts are illustrated in Figure 14.1.

It is necessary to know the meaning of the following concepts: Core business activities and Core product. Core business activities are the original reason for the company's initialization. The organization's mission is usually the same as its core business activities. The core product is the vehicle used to satisfy the core business activity.
14.6.1. **Five basic parts of the organisation as identified by Henry Mintzberg:**

The organization consists of five basic parts, which are: a) Strategic apex; b) Technostructure; c) Middle line; d) Support staff; and e) Operating core. [F.16] & [F.19] Figure 14.1. illustrates the relationship between the parts graphically.

![Diagram of the five basic parts of the organization]

*Fig. 14.1.*
a) **Strategic apex.**

The strategic apex is the home of top management, where the organization is managed from a general perspective.

b) **Technostructure.**

The technostructure includes the staff analysts who design the systems by which work processes and outputs are standardized in the organization.

c) **Middle line.**

The middle line comprises all those managers who stand in a direct line relationship between the strategic apex and the operating core.

d) **Support Staff.**

The support staff comprises all those specialists who provide support to the organization outside of its operating work flow — in the typical manufacturing firm, everything from the cafeteria staff and the mail room, to public relations.

The information department is classified under this part of the organization because the information department provides a service to the rest of the company.

e) **Operating core.**

The operating core is where the basic work of producing the core product or service is performed.
Each of these parts exercises a force. The strength of the force determines the structure of the organization.

14.6.2. Forces as identified by Mintzberg:

Mintzberg identified five forces which each part of the organization exerts. [F.16] The forces originate because each part in the organization wants to grow. As the organization grows one part expands faster than another, because this part has a higher strategic value. [F.19]

If an imbalance occurs, it must be redressed by management otherwise it will cause internal conflict and may even make the organization unmanageable.

![Diagram of Pull forces in an organization](image-url)
We propose that the forces interact with each other, as can be seen in Figure 14.2.

a) **Centralization.**

The strategic apex has a natural tendency towards tight control and direct supervision. This causes vertical and horizontal centralization.

b) **Standardization.**

The technostructure encourages coordination by standardization of the work process throughout the organization.

c) **Balkanize.**

The managers of the middle line try to balkanize the structure. By drawing power from the strategic apex and by delegating as little as possible, the middle line can obtain an array of power.

d) **Mutual adjustment.**

The support staff prefer collaboration. They prefer working together in groups whose tasks are coordinated by mutual adjustment.

e) **Professionalism.**

The workers of the operating core prefer autonomy above all, which can occur if jobs are highly standardized. They want to make more decisions on their own.

The arrows in Figure 14.2. indicate the direction of these forces. The stronger the force, the larger a certain part will
become. The larger a part, the greater the power it has over the rest of the organization. The only way to rectify this endless loop is by restructuring the company.

The information department is part of the support staff. We sketch a few scenarios of what to do if support staff are attracting too much power. The strategic importance of information will have a direct influence on the size and power of support staff and, more specifically, the information department.

Because the support staff are growing, due to the importance of information, it will cause an imbalance in the organization. This imbalance will cause conflict between the support staff and the rest of the organization. The imbalance in the organization is illustrated in Figure 14.3.
The objectives of the support staff may start to conflict with the company's core business activities objectives.

Top management must decide if they want to diversify. If they do, the information department must be given the same status as other departments.

Thus the information department must have a say in the strategic apex of the organization. This can be achieved by making the information department a Strategic Business Unit (SBU).

14.6.3. Strategic Business Unit (SBU).

A Strategic Business Unit (SBU) must have a) an unique mission; b) identifiable competitors; c) an external market focus; and d) control of its business functions. [F.17] Strategic business units must all have approximately the same strategic value for the organization.

Top management must see the information SBU as an independent unit, just like all the other SBU's. A SBU has the prerogative to use funds for projects as approved by management.

SBU's have all the same strategic importance, they must all contribute equally to company-wide strategies and objectives. All SBU managers have an equal chance of being elected to the board of directors. In Figure 14.4, it can be seen that the information SBU is on the same level and the same size as the other SBU's.
If top management decides not to diversify from the core business activities, the strategic imbalance can be redressed by restructuring the support staff to form a new company. This new company then specializes in information technology.

14.6.4. Create a new company.

The information is so important to the company that it has to diversify to rectify the structural imbalance.
By creating a new company the organization does not need to diversify but can still have access to, and control over, its information resources. See Figure 14.5. Examples of this are GIS of Sasol and AIS of AECI.

Fig. 14.5.

A more specialized service can be provided to the mother company and better work satisfaction can be obtained by staff members. The mother company can continue to concentrate on its core business activities without any internal imbalances.

Some companies do not realize the strategic value of information technology. Information technology and its effective man-
Management is not seen as a key success factor for the organization.

14.6.5. Information manager reports to the financial manager.

In Figure 14.6, it can be seen that the support staff is larger than the technostructure. There is thus an imbalance in the organization. This imbalance is either regarded as temporary or as not large enough to justify restructuring of the organization.
The information manager reports to the financial manager. The financial manager exercises line authority over the information manager. An example is ESCOM.

If this imbalance continues on a large scale over long period and is not addressed, the following problems may develop:

- Bad work flow.
- The information department forms a sub-culture.
- Information personnel is not in touch with the needs of the rest of the company.
- Uncertain occupational growth.
- Information department has a lack of vision which causes lower productivity and work satisfaction.
- Lack of influence on the company strategy.

To help top management in restructuring the organization they have to know what the organization is supposed to look like in the 1990's.

14.7. Some features of organizations in the 1990s.

Organizations in the 1990's will have flatter structures, with fewer levels of management so that they can process information faster and be more responsive to changes in the environment. [F.20]

Managers will no longer have the knowledge which their workers possess, so they will move towards becoming 'coordinators' of experts rather than 'controllers' of subordinates.

There will be greater use of cross-functional teams so that organizations can coordinate activities to occur simultaneously.
rather than sequentially. This will aim at cutting down product development times and dealing with more complex problems. This is a good example of the influence of the support staff and, more specifically, the information worker has on the organizational work flow.

Organizations will improve the way they develop and communicate their strategies, as there will be no time to wait and see what competitors are doing and to follow them.


Change takes place no matter what deters it. This chapter has examined the effect of change in information technology on the organization and more specifically, on its structure. We propose scenarios of the impact that information technology might have on the structure of the organization.

If top management have created "a culture of change" this will make the organization more responsive to market changes, both in its core business and in information technology.

The management of change is a sensitive issue. There is not only personnel resistance but management, like all people, do not like change in their environment. This highly sensitive issue must be managed in a orderly and objective fashion. There must be a realization of major problems associated with people and their feelings towards change. These problems must be addressed. By ignoring change it is only postponed to a later stage, when the effects of the change could be more intense.

-oOo-
Chapter 15.

Software Program.

Ideas often flash across our minds more complete than we could make them after much labor.

La Rochefoucauld, Maxims

15.1. Introduction.

This chapter discusses a software program we developed which can be used to reduce inventory. This program will be referred to as SIMSTOCK. The subsequent section will examine the functions of the program in brief.

15.2. Introduction to SimStock.

The software program we developed takes estimated demand (or forecasted demand), calculates simulated demand and then plots the information graphically on the screen.

The forecasted demand can be obtained from commercially available forecast software. Currently the data has to be keyed in, but a direct link can be developed to read a forecast package's data files.
Based on the forecasted demand simulated demand is calculated as follows: 6 random values are generated. These values cannot be 50% more or less than the forecasted demand. The average of the random values are then calculated, the result is the simulated demand.

The inventory level deteriorates due to the subtraction of the simulated demand. The initial inventory level is used as base and each simulated demand per period is subtracted from the base. The time period can be one day, one week or a month. If the inventory level reaches the re-order point or buffer size a production run is scheduled.

The number of units produced per production run is referred to as the lot size.

The buffer size or re-order point is the minimum amount of inventory that must be in stock. The smaller the buffer size the less the inventory level and the greater the savings. The risk with a small buffer size is the risk of stock-outs. The risk of stock-outs increases as the buffer size decreases.

The following graphs can be displayed on the screen:
- Estimated demand
- Simulated demand
- Inventory level
- Re-order point

Each one of these graphs can be made active. If a graph is active (Squares will appear on the line) the user can drag it around on the screen and see how it influences the other graphs. This creates a "What if" type scenario.
The subsequent section will examine the screens of the program in more detail. Each of the pull-down menus are discussed and any important facts about menu options will also be discussed.

15.3. The User Interface of SimStock.

This section examines the user interface of the software program.

The start-up screen has the following options to choose from:

- File
- Inventory
- Default
- Graphics
- Options

By depressing ALT and the highlighted letter, in this case the first character of the word, the relevant pull-down menu will appear.

Hot Keys appear at the bottom of the screen. The hot keys are as follows:

ALT + X — Will exit the program.
F2 — Will save the current file. There must be a current file to save, a current file is created by using the Create new file or Open existing file option.

F3 — Opens an existing file. The full path and file name with extension must be typed in.

F4 — Creates a new file. The full path and file name with extension must be typed in.

ALT+F3 — Will close any active or open windows.

When you want to use the mouse make sure the mouse is initialized before running the program, then simply choose an option. An option is chosen by pointing the mouse at the relevant option and pressing the Left hand Button (L/B) of the mouse (This is referred to as clicking on an option). This will have the same effect as using the hot keys.

If a pull-down menu is active the arrows can be used to move between menus and up and down within a menu.

In Figure 15.1. the File pull-down menu is illustrated. This menu contains all relevant commands relating to files.
Most of these options have hot keys and were discussed previously. The Save as option allows you to save under a different name.

In Figure 15.2, the Inventory pull-down menu is illustrated.
The Inventory pull-down menu consists of two options: Inventory policy and Time span of policy.

The inventory policy can be one of the following:
- Liberal
- Moderate
- Conservative

An expert system can be used to determine the inventory policy. The higher the risk of stock-out the more conservative the policy.

The inventory policy in conjunction with the following option, the Time span of policy, determines the size of the buffer inventory.

There is a choice of three different time spans. Option (1) 2 4 6 means if the inventory policy is conservative, 6 days (intervals) of inventory must be in stock. If the policy was liberal only 2 days of inventory should be in stock. The smaller the Buffer stock the greater the chance of stock-outs. The time span can be overridden by the Buffer size.

Figure 15.3. illustrates the Default values. When choosing to Create a new file the program will lead you sequentially through this menu.
Default Pull-down Menu.

Lot size
Initial inventory
Buffer size

Estimated demand

Fig. 15.3.

When a file already exists, the default values can be overridden by using the Default pull-down menu.

Figure 15.4. illustrates the menu that will display the Graphics on the screen.

Graphics Pull-down Menu.

Estimated Demand
Simulated Demand
Inventory Level
Re-Order Point

Fig. 15.4.
Figure 15.5. is an example of a graph. There are two graphs on the same axis. The one with the dotted line is the passive graph, the one with the solid line and small squares is the active graph.

**Re-order Point Graph**

C - Calculate  P - Print
R - Re-Draw    Q - Quit

--- Inventory Level

--- Reorder Point

Fig. 15.5.
The *active* graph can change by pointing the mouse at a square and pressing the *Left* hand Button (L/B) (while the L/B is pressed move the mouse up and down). This is referred to as dragging of a square.

During the dragging process the *passive* graph will not be re-drawn, because of this it may happen that the *passive* graph appears "jagged". Simply press R to Re-draw the screen. The squares on the screen will change color when they are move.

By pressing C the graph will be recalculated and re-drawn.

P will make a printout of the graph. Please note: *the DOS program Graphics.Com must be loaded before this program is run.*

Q will quit the graph.

**Options Pull-down Menu.**

<table>
<thead>
<tr>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculator F9</td>
</tr>
<tr>
<td>Dos Shell</td>
</tr>
</tbody>
</table>

Figure 15.6. illustrates the last pull-down menu.

Fig. 15.6.
15.4. Assumptions.

It is assumed that there is no lead time (delay) and the product is manufactured the same day (or time period) it reaches the re-order point.

15.5. Points to remember.

Only the first 18 values are currently used as output to the graphs.

When running the DOS SHELL make sure there is a Command.Com in the current drive or a path to it.

When the estimated demand is zero or less than zero a run time error will occur due to division by zero. Please ensure that the values used are larger than zero.

The scale of the Y-axis is determined as follows: the average of the active graph’s values are determined except the largest and smallest value. The largest and smallest values are not used because there is a grave risk that the values might be incorrect, due to typing errors. The average is the point from where all the values are plotted.

Though it is a bit difficult to read values from the graph we felt that it was more important to see what effect the changing of one value has on another. Any value can be used as input and it will be plotted on the screen.
15.6. System Requirements.

The software program was developed in Turbo Pascal 6.0. The source code is about 5000 lines.

Hardware requirements:

IBM compatible 8086, 80286 or 80386 computer.

A VGA color screen.

At least one 360K floppy drive.

Micro-Soft mouse or compatible mouse.

Parallel Printer is optional.

Software requirements:

MS-Dos or PC-Dos 3.0. or Higher.

Graphics.Com must be executed before starting the program. This enables the computer to print the graphic screens.

Gmouse.Com, Tecmouse.Exe, Mouse.Com or Mouse.Exe is required to initialize the mouse.

15.7. The execution of the included program.

The included 360K floppy is a bootable disk. Simply insert the disk in drive A and switch the computer on. The relevant programs will execute. Ensure that a Micro-soft compatible mouse is plugged in.
Choose the Open existing file and type Data2.dat. This is a pre-defined data file.

For more information on the software and screen lay-out see section 15.3.

15.8. Conclusion.

This chapter has examined the software program we developed.

The subsequent chapter will be a management review of the study.

-oOo-
Chapter 16.

Management Review.

16.1. Introduction.

This chapter serves as a short management review of some of the more important aspects addressed in this study.

Automation of a factory has to go through certain stages. These stages are referred to as Manufacturing Strategies. These strategies are:

a) Manufacturing Resource Planning Strategy (MRP II).


c) Computer Integrated Manufacturing Strategy (CIM).

d) Inter Organizational Information Sharing Strategy (IOIS).

Each of these strategies have a pre-defined inventory policy. The main policies are Just-in-Case (JIC) and Just-in-Time (JIT).

The first two manufacturing strategies have a Just-in-Case (JIC) inventory policy and the last two have a Just-in-Time policy. The inventory policy transforms between CADCAM strategy and CIM strategy.
Each strategy is critically evaluated using the following criteria: definition of strategy, main advantages and disadvantages of strategy. For more detailed information on each strategy investigate the relevant chapters.

We need to define the manufacturing process before the various manufacturing strategies can be discussed.

16.2. What is manufacturing?

Manufacturing is the process that adds value to raw materials by transforming them into a more desirable state. Various inputs are used to help in the transformation process. These inputs are: equipment, tools, energy and labour. The manufacturing process is illustrated in Figure 16.1.

![Manufacturing process model](image)

Fig. 16.1.

Each of the manufacturing strategies are critically discussed in the rest of the chapter.
The first manufacturing strategy to be discussed is Manufacturing Resource Planning (MRP II).


16.3.1. Definition of MRP II.

MRP II is the linking of material requirements planning (MRP), capacity-requirements planning and the master production schedule.

16.3.2. Advantages of MRP II.

Some of the important advantages of manufacturing resource planning are listed here.

- Reduction in inventory. A certain degree of stock management is better than none at all. This was discussed in more detail in section 8.6.
- Quicker response to changes in demand.
- Reduced setup and product changeover cost. Everything is planned ahead so everybody knows what to do, which makes them more productive. [D.19]
- Better machine utilization. The bills of material gives all relevant information so that the final assembly schedule can make maximum use of available machines. [D.24]
- Improved capacity to respond to changes in the master schedule, and as an aid in the development of the master schedule.
Because MRP is directly linked to the master production schedule the response in the MPS is very fast. [D.22]

16.3.3. Disadvantages of MRP II.

To get the maximum effect of MRP II one should be aware of the main disadvantages.

- MRP II is data intensive or data hungry. Input data must be accurate. MRP II does not have functions that test the integrity of the data. If the bill of material is not accurate, too much or too little of a product will be manufactured. According to Greene [D.18] accuracy of 98 percent or greater is necessary, or else the correct requirements cannot be exploded down through the lower levels. This is also the case with inventory. A good MRP II system needs an inventory record of 95 percent or better. This is a good example of GIGO — garbage in garbage out. [C.23]

- The master production schedule (MPS) is the master of material requirements planning. If the MPS is not managed well, the other activities will not overcome this weakness. [C.30] Even today, a typical company will have unrealistic master scheduling. This is because too many companies put their "hope and dreams" into the MPS rather than what they can do.

- MRP II is not interactive and the results are out of date the minute they are generated. It cannot respond to unforeseen changes. It does not change the computational parameters on an interactive basis.

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The linking of Computer-Aided Design and Computer-Aided Manufacturing form the CADCAM strategy. The CADCAM strategy is examined in the following section.

16.4. Combining CAD & CAM.

16.4.1. Definition of CADCAM.

It should be noted that CADCAM is an integration of design and manufacturing activities by means of computer systems. The purpose of CADCAM is to integrate the independent CAD and CAM computer systems. This will reduce duplication of effort by design and manufacturing personnel.

16.4.2. Advantages of CADCAM.

Main advantages of CADCAM are the following.

- Reduced production lead time. The lead time is reduced because products that are manufactured in a similar fashion can be scheduled, one after the other.

- Faster response to requests for quotation. Because the automated islands are linked there will be a quicker response to clients needs. [C.28]

- More evenly distributed workload. If the design process were automated, it would be completed faster than manufacturing can handle. [C.28] This will create a backlog of information that needs to be imported into the manufacturing process.

- This risk and loss of integrity is minimized by using automated links between the components of the CADCAM system. [D.18]
The exchange of information and ultimately knowledge is encouraged. The quality of decisions is much higher due to the fact that the decision is based on a broader base of information.

- Better cost control. Management can see where the problem areas are that need to be addressed. [C.34]

- More customer input into designs. The design process is much easier and the need to redesign products is less. [B.8] The hands of the designer are free to design products more appropriate to the customers' needs and wants.

- The scheduling of machines can be optimized by using proven and well tested algorithms. [D.26] The company only need to customize algorithms to suit their own specific needs.

- Engineering manpower reduced. Past mistakes can be remembered by the system, which will ensure that the same mistakes are not made twice. [D.28] The scheduling of machines can be done by computers.

16.4.3. Disadvantages to CADCAM.

The following are stumbling blocks in the way of implementing CADCAM successfully.

- The facility is inappropriate for the task. [C.28] A lack of commitment by the user and the developer during the design phase will lead to indifferent user requirements.
Users fear the facility and prefer to use conventional methods. Few people accept change without any apprehension. User training must be provided as well as adequate time to phase out conventional methods. The phasing out must be in accordance with a phasing out plan.

The third manufacturing strategy Computer Integrated Manufacturing is now examined.


16.5.1. Definition of CIM.

In Computer Integrated Manufacturing (CIM) the goal is to tie all the various computers, and other programmable devices found in the factory into one integrated network.

16.5.2. Advantages of CIM.

Some of the major advantages of CIM will now be discussed.

Computer integrated manufacturing has a positive influence on an organization from the quality of the product right through to the creation of an environment conducive to innovation and change.

Tedious and monotonous jobs are the easiest to automate, which leads to higher work satisfaction for workers and stimulates them to perform better.
The automation of the factory creates safer working conditions for the worker. Since there is less physical participation by the worker in the production process.

Engineering and design costs drop. The automation of the design process reduces the time it will take to produce new and innovative designs. This will reduce development costs and time. Because development of products is much faster there can be a closer correlation between the consumer's (user) needs and wants, and that which the company provide.

Due to the culture of innovations and change, as created by management, employee morale is higher. The environment is more conducive to innovations and free thinking.

CIM can improve capital resource productivity, as it makes better use of capital resources, by helping the manufacturer to use fewer machines, lower inventory and less space to achieve greater output at lower cost.

CIM offers greater volumes through greater variety, letting you spread your major investment in CIM over many different products, with the total number of units creating economy of scale for profitability.

The flexibility of CIM gives you the ability to be first into the marketplace, to gain significant market share before competitors can catch up.

In order to maximize the advantages of CIM, the disadvantages of CIM must be examined.
16.5.3. Disadvantages of CIM.

- The main problem with CIM is that it demands change from old and well-known forms to a new look at the organization, its structure, culture and products. This is a problem since humans are reluctant to change. Management of technological change was discussed in chapter 14.

- Another major reason why CIM is not implemented properly might be that the company is fighting merely to survive, and does not have time to adapt to the new technology.

- Common data structures, especially between CAD systems and material requirements planning (MRP) systems are not available. [C.33]

- Common 'human interfaces' have not yet been developed for CIM components. Even within CIM components, there is a broad variety of dialogues offered by different vendors. [C.33] This confuses the user and muddles the choice of CIM components.

An all new manufacturing strategy Inter Organizational Information Sharing, was discussed in detail in Chapter 12, and is critically evaluated here.

16.6. Inter Organisation Information Sharing (IOIS).

16.6.1. Definition of IOIS.
Inter Organisation Information Sharing or IOIS can be defined as the exchange or sharing of information, data and/or information services by vertical chain members.

When considering the information to be shared the following must be examined: the relevance of the information, the costs of the information, how sensitive the information is, how much it will cost to protect this sensitive information, how much damage this information will cause if it leaks out, and whether the risk taken is less than the advantages gained from the legal use of this information.

16.6.2. Advantages of IOIS.

The main advantages of IOIS are summarized here.

☑ Enhances user satisfaction.

☑ Reduces administration costs.

☑ Reduces paper flow between companies.

☑ Reduces lead time.

☑ Faster response to market changes.

☑ More accurate forecasting.

16.6.3. Disadvantages of IOIS.

☑ Success of IOIS depends on co-operation between the channel members.
Management review

- Risk of malicious attack.
- Long term to implement and reach an agreement.
- What about legal aspects?

The following section highlights the divergence between Just-in-Case and Just-in-Time inventory policies. The transformation from a JIC to a JIT inventory policy takes place between the CADCAM manufacturing strategy and CIM strategy.


The ideal of Just-in-Time (KANBAN in Japanese) is to have the part available at the next stage of processing the instant that stage is ready for the part. [C.23]

The ideal of Just-in-Case (JIC), on the other hand is that parts are made in advance in case something goes wrong with the previous process so that there is enough in stock to continue. The result is that parts are made for stock and not for the consumer. JIC is based on the forecast demand for a product and not the actual demand.

With Just-in-Time the part must be of high quality and must be delivered as promised. A delivery delay can cause the shutdown of the entire operation. This simply must not happen. Scheduling must be perfect and machines must be in perfect working condition. [C.23]

Extensive analysis of machine functions, tool requirements, and all other aspects of the system is required. This will lead
to contingency planning; breakages are anticipated and steps are taken well in advance to minimize the effect of the break.

Fig. 16.2.

Figure 16.2. illustrates ideal JIT and JIC production systems. In the case of JIT demand is equal to the company's capacity. The average demand for a product coincides with the company's ability to produce the product over time. In a JIT system the capacity of the company is equal to the maximum de-
mand. This is not the case in a JIC system, where the average demand must equal capacity.

The transition from a JIC inventory policy to a JIT policy needs time. Both management and the work force need the time to adopt the new JIT strategy.

16.8. Conclusion.

This chapter has done critical evaluation of the various manufacturing strategies discussed in this study.

The subsequent chapter will examine areas that need further research.

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Chapter 17.

Closing remarks.

I always have the impression of being much further away from a thing I "understand" than when I don't understand.

Theodor Haecher, Journal in the night

17.1. Introduction.

This chapter gives a short summary on the subjects discussed in this study and highlights aspects and/or questions that need further research.

17.2. Summary.

This study discussed the use of Artificial Intelligence (AI) and Expert systems (ES) in the manufacturing environment both now and in the future. AI concepts have a natural development environment in manufacturing from computer vision through to the more effective management of databases.

Processes that was addressed was Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Manufacturing Resource Planning (MRP II) and Computer Integrated
Manufacturing (CIM). Each of these processes were critically examined. The wide scale use of CIM is limited due to the enormous expenditure needed to implement it and the massive structural and cultural changes needed. The impact of information technology on the internal structure and culture of an organization was subsequently discussed.

We propose an extension to CIM — Inter Organizational Information Sharing (IOIS). IOIS is not only an extension to CIM but can be used as an alternative to CIM. Types of information to be shared depend largely on the willingness of chain members to cooperate. Ways are proposed to implement IOIS. These ways need to be expanded and implemented to see which one is the most appropriate. We feel that a blackboard type system will be the easiest to implement with the smallest security risk.

We developed a software program for assisting with the management of inventory. The program can handle “What If” type questions and will help the user to determine the most effective lot size and re-order points.

The subsequent section examines future research areas.

17.3. Future Research.

Unresolved aspects and unanswered questions are discussed in this section.

Alternative means are required to gain the benefits of CIM without the enormous capital investment and high running
costs. This is especially true for small to medium sized manufacturers in this country.

There is a lack of support tools for the small to medium sized manufacturer. They need a simple plan to follow to reach CIM and ultimately IOIS. This plan must lead them from where they have no prior knowledge of information technology to a complete information integrated internal organization and ultimately to a completely integrated vertical chain.

- Lack of off the shelf expert system based management support software.
- Lack of intelligent design advisors (Intelligent CAD).
- Lack of effective and flexible computer vision systems.
- Information is still fed into the system by people, people are prone to make mistakes. How about automated information input.
- There must be a move towards real-time systems like real-time schedulers and real-time intelligent report writers.
- The outlook of current manufacturing software is to "build stock" rather than to meet demand. There is a lack of support for make-to-order companies. Make-to-stock companies have enjoyed a large piece of the research cake.
- Start to build security in manufacturing software. This will help stop the mentality of build now and secure later at enormous costs.
More cross functional inputs are required when developing software.

The impact of CIM and IOIS on the culture and structure of the company need to be redressed before and after it is implemented. Companies need an information strategy, such a strategy must have a well defined and reachable goal.

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Other.


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Appendix B.

Distributors of software packages.

**Authorized HORNET dealer.**

Claremont Controls Limited.

Albert House

Rothbury

Morpeth

Northumberland, NE65 7SR

England

**Authorized Rapier dealer.**

SQL Systems Europe

Marconistraat 16

3029

AK Rotterdam


**Authorized Kinetix dealer.**

Hiperformance Systems

Private Bag

Wendywood

2144

South Africa

**Authorized AutoCAD dealer.**

AFRACAD (Pty) Ltd

P O Box 4276

Rivonia

2128

South Africa

**Authorized AutoCAM dealer.**

AFRACAD (Pty) Ltd

P O Box 4276

Rivonia

2128

South Africa
Authorized AutoCAD dealer.
Allyson Lawless Systems (Pty) Ltd
P O Box 73285
Fairland
2030
South Africa

Authorized MicroDUCT dealer.
AFRACAD (Pty) Ltd
P O Box 4276
Rivonia
2128
South Africa

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