Chapter 2 Literature Review

2.0 Production Planning Methods

This chapter on the literature review is about the manufacturing sector that entails the planning and production of a manufacturing plant. Along with this are methods and techniques such as Manufacturing Resource Planning (MRP II), Just-in-Time production (JIT), Total Quality Management (TQM), Inventory Management, and not the least, Distribution Resource Planning (DRP). These techniques which also include Master Production Scheduling (MPS) to sales and operations planning are necessary for operating a successful manufacturing enterprise, combined with the computerised, automated computer-aided systems used for production purposes.

MRP II is a systems approach to manufacturing, aimed at the elimination of all excess inventory. MRP II systems provide management with forward visibility so that problems can be anticipated and resolved before they get out of hand. They have been implemented by thousands of companies worldwide.

JIT is a Japanese production system that requires precisely the necessary units in the necessary quantities at the necessary time, with the objective of achieving exactly according to schedule, which is more applicable to a repetitive manufacturing process.

TQM is a structured system for satisfying internal and external customers as well as suppliers by integrating the business environment, continuous improvement, and breakthroughs with development, improvement, and maintenance cycles while changing organisational culture. Pinpointing internal and external requirements allows a company to continuously improve, develop, and maintain quality, cost, delivery, and morale. TQM is a system that integrates all of these activities and information.

MPS is the plan that states what is to be produced, how many are to be completed and when they are to be completed [Smith87]. The purpose of DRP is to improve customer service levels by anticipating customer demand at distribution centers and providing finished products at the correct location when customer needs arise as well as providing an accurate requirements plan for manufacturing. These techniques mentioned are widely used in the manufacturing sector.

The literature review covers a broad spectrum of the manufacturing process which consists of many components found in the production line from start to finish. An overview of the manufacturing process will be covered while the end focus is into the production planning domain which is the core of this research.

2.1 The Manufacturing Process

The manufacturing process is a production process to assemble a finished product within a fixed procedure in a way that is consistent with costs and quality. It is done from the start when an order is taken and end when the product is delivered to the customer. Effective use of the planning capabilities can substantially reduce the inventory required to meet customer demands.

Although, this seems like a straight forward task, this is far from easy because production planning and control are the two most crucial factors in the entire manufacturing process in determining the success rate. To be effective in these areas, manufacturing systems must be used to do planning and control. Most companies have their respective, computerised manufacturing systems to assist in the production process. The most widely used is the manufacturing resource planning (*MRP II*), which consists of a number of interconnected modules or subsystems that are used to manage all facets of production and inventory control.

2.1.1 Components in Manufacturing Planning

As mentioned in the earlier section that there are three main components of planning which are strategic planning, master management planning as well as executive planning and control. Strategic planning which is undertaken by the top management, controls the business, marketing and production planning of the entire plant.

Strategic planning involves a very high level of planning as they are concerned with the business goals, projections of turnover, marketing strategies and production quantities which are all in line with reasons for the plant's existence. The plan sums up the total amount of output that manufacturing is responsible to produce for each period in the planning horizon.

On the other hand, the Master Management planning, consists of master production scheduling and materials requirements planning that states what is to be produced, how many are to be completed, and when they are to be completed given the time frame. This also involves capacity planning which is used to evaluate the capacity requirement and to plan the best way to make the capacity available in line with the desire to determine the least costly way to meet the capacity needed. The material requirement planning is aimed at controlling purchasing and manufacturing components needed for the operation of a production program. It determines the relationship between raw materials, component parts, sub-assemblies and completed products which come under bill of materials required for the production process to start.

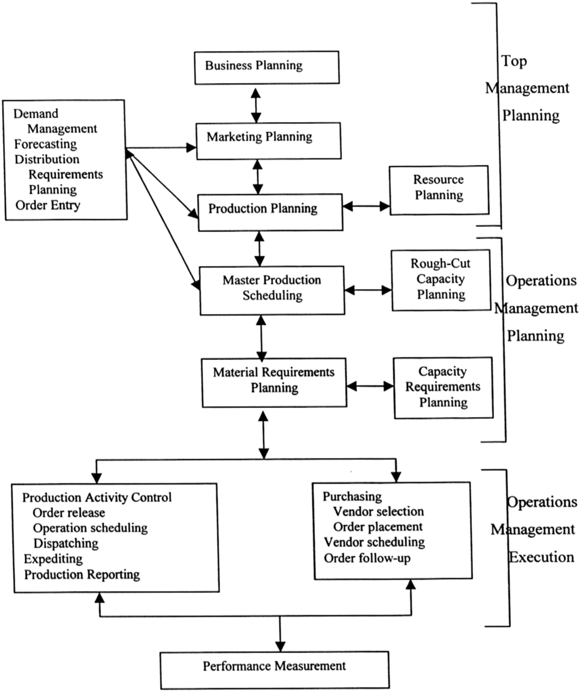
Under the Execution Planning and Control, it includes production activity control and performance measurement. It is crucial for the constant monitoring of production activities so as output is consistent over time and there is no delay in delivering goods to customers. Performance measurement enables management to evaluate how well the system is operating, highlights trouble areas and points up the need for corrective action. Manufactured goods are also measured in terms of quality and quantity produced, as this can affect the scheduling process if it goes out of control, which as a result, would delay the factory-on-time-delivery (FOTD) , and thus leading to late delivery to customers.

2.1.2 Manufacturing Resource Planning – MRP II

Manufacturing Resource Planning (MRP II) is a systems approach to manufacturing, aimed at the elimination of all excess inventory. It is the most widely used and successful computer-based production and inventory control which contains powerful tools for more effective manufacturing management through the use of better planning and control concepts and techniques. As mentioned, MRP II systems provide management with forward visibility so that problems can be anticipated and resolved before they get out of hand. When properly implemented and embraced by an organisation as a formal approach to managing the business, MRP II seldom fails to fulfill its promise which is providing a significant reduction in inventory and operating costs as there is improved control over the entire production operations.

This system consists of a number of interconnected modules of subsystems, which are used to manage all facets of production and inventory control. Figure 2.1 (adapted from Spencer B Smith , : *The Manufacturing Resource Planning - MRP II* : Computer Based Production and Inventory Control, Pg. 9) illustrates in detail the whole MRP II system.

Figure 2.1 The Manufacturing Resource Planning - MRP II



The MRP II System is divided into three sections :

i. Top Management Planning

This level is responsible for the strategic planning of the production business. It consists of four subsystems which are business planning, marketing planning, production planning and resource planning. The planning process must be coordinated to reach an agreement for the benefit of the company. These plans are long-term plans that extend through five years in most companies. The production planning is closely related to resource planning as the resource plan subsystem determines the capacity required to meet the production plan. The arrows indicate information flows downward from a higher level, for example, business planning, which are transmitted downward to become more detailed plans made at a lower level which is the production plan. Related to the top-level management is demand management which covers all the activities involved in recognising the demands for the company's products and capacities, and organising them in a form suitable for input to production planning and master production scheduling. This includes forecasting, distribution requirements planning (inventories in regional warehouses), order entry and interplant shipments.

ii. Operations Management Planning

This level is in charge of the details of the plant's operations which is made up of master production scheduling (MPS), rough-cut capacity planning (RCCP), material requirements planning (MRP) and capacity requirements planning (CRP). The MPS is a plan for the quantity of end items which are to be produced according to the planning schedule. It is actually a breakdown of the production plan into a manufacturing program with details of specific end items which are to be manufactured. The RCCP determines the capacity needed to produce the MPS. It does not contain much detail of the capacity required for the MPS (hence the term 'rough-cut'). RCCP shows the man or machine hours needed by department or work center by planning period.

The MRP uses the bill of material, lead times and inventory availability information to explode the MPS and plan orders for components and materials needed to support the MPS. The plan includes order quantities and due dates for delivery of completed goods. The CRP uses the MRP and routing data to determine capacities required by planning period and work center. CRP is more accurate than RCCP because they are based on planned orders for components and take into account order timing, current inventories, lot sizing and orders already delivered. If needed, available capacity may be adjusted by the use of overtime, increasing the number of machines or even subassembly some operations. CRP considers utilisation percentages of machines, personnel and labour force efficiency to determine realistic capacities. Reports and inquiry by work center highlight overloaded and under loaded areas, allowing work to be replanned or capacity adjustments to be implemented. If an acceptable capacity plan cannot materialise, then the MRP and the MPS must be revised.

iii. Operations Management Execution

This operation tasks involve the execution of the entire production plan that are passed down to the assembly line for production to proceed. It consists of production activity control (PAC), purchasing of input materials and performance measurement.

The PAC includes the release of job orders planned by MPS or MRP to the assembly line, operation scheduling that states how jobs will be run at a given work center, determining lead times and controlling orders that are behind schedule. It also includes production reporting about the job progress. These are measures of checking to ascertain that production does not fall out of schedule, instead following closely their production plan.

The purchasing functions consist of selection of vendors for production materials, placement of purchase orders according to the time requested for the arrival of inputs, vendor scheduling on raw materials as well as their follow-up orders. Performance measurement allows management to evaluate how well the whole system is operating, indicating when and where production problems arise and how to address those problem areas. Some of the key areas include data accuracy, correct forecasting, smooth schedule performance, and not the least, customer service.

2.1.3 Production Planning Domain

As mentioned earlier, the focus of this research is in the area of production planning, therefore this section onwards will deal with the emphasis on the research into the background for the development of a customisable production planning tool. In order to have a better understanding, it is necessary to zoom in on the production planning domain.

The purpose of a production plan is to develop a logical sequence of production in order to obtain efficient output while also satisfying market demands. In order to plan for production, there are a number of factors to be considered so as to produce an effective and accurate plan. A production plan must have the following components which are actually inputs to the plan :

a. Customer demand which contains the order plan that shows the customers' schedule of demand for the products ordered and their expected delivery dates.
b. Forecasting figures which show the monthly forecast of the products to be produced for at least six months ahead of schedule. An accurate forecast is important so as to produce an accurate plan.
c. Inventory data that will determine if a plant will produce goods that are make-to-order or make-to-stock, or both. If it is the former, then there will not be any inventory involved, otherwise accumulated stock must be properly managed so that the plant's working capital is not tied up in the form of inventory.
d. Backlog is an input that acts as a yardstick to the plant particularly as a measurement of a plant's efficiency in meeting delivery orders that are still outstanding to its customers. This needs to be cleared up so as not to disrupt production, thus allowing on time delivery with minimal delay to customers' orders.
e. A proper schedule is needed to show the delivery dates and shipments to customers. This is done in line with the Factory On-Time Delivery (FOTD) so that all expected time of deliveries can be met.

These inputs are all netted into the production plan together with the management policies before the plan is checked against sufficient capacity in order for production to proceed. A good application system with a flexible and robust architecture for this production planning tool is the aim of this object-oriented software engineering process. The next section looks into the research survey, findings and analysis of the production planning application system.

2.2 Research Survey and Analysis

In order to have a better grasp of the planning framework, a research into production planning was carried out in a semiconductor plant, which as mentioned in Chapter 1, at Motorola Semiconductor, Kuala Lumpur (KLM), where an onsite study was done on the entire production process and how it was done in the actual work place. The manufacturing process of this plant entails enormous amount of planning and scheduling of semiconductor chips used mainly for automobiles, mobile handsets, computers and telecommunications, to name some of the manufactured products. The next section will describe an overview of the company's product sector.

2.2.1 Motorola Incorporated and Motorola, Kuala Lumpur (KLM)

Motorola is a US based company with its headquarters in Chicago. It has a worldwide population of approximately 150,000 employees and has scores of facilities around the world, working to improve life with thousands of electronics products.

Motorola's range of products include semiconductors and two-way radio communications equipment, automotive electronics, cellular telephones, and data communications and equipment for government service and space exploration. This list is by no means exhaustive.

The company is made up of five sectors:-

a) Semiconductor Product Sector

b) General System Sector

c) Messaging, Information and Media Sector

d) Land Mobile Products Sector

e) Automotive, Energy and Controls Group

Motorola Kuala Lumpur (KLM) is part of the Semiconductor Products Sector. It was established in 1972 and has four thousand employees. The organisation in KLM is responsible for the assembly and testing of Integrated Circuits. The product portfolio in KLM are as follows:-

a. Microcontrollers

b. Memory Chips and Modules

c. Analog Integrated Circuits

d. Digital Integrated Circuits

The customers served by KLM serve are mainly the Automotive Industry, Computer and Telecommunications Manufacturers, and Original Equipment Manufacturers (OEM) Industries.

KLM's customer base are worldwide namely, Asia Pacific, China, Japan, Europe and North America. Motorola Inc. has worldwide sales of approximately US30 billion dollars in 1997, of which the Semiconductor Products Sector contributed 28% of the sales. KLM's annual contribution to sector sales is approximately 25% or USD2 billion.

2.2.1.1 KLM Setup of Functions

KLM is a manufacturing factory specialising in the assembly and testing of semiconductor products. The role played by KLM in the corporate organisation are operational functions. Its main objective is to ensure the component parts of the organisation in terms of resources, processes, people and skills are put together to effectively deliver products and services, so that the marketing business units (MBUs) are successful in dominating the markets in which they have chosen to participate.

In the KLM organisation structure, there are 14 fourteen departments. Each department is a specialised function. There are five operations departments which are involved in the assembly and testing of products. Of these five operations, three of them focus on assembly of semiconductors while the other two specialised in the testing of semiconductors. The remaining nine departments within the KLM organisation are support departments. They are human resources, reliability and quality assurance, finance, materials, strategic management and skills development, total productive maintenance, site services, and research and development. KLM organisation structure is complex and effective integration of all the departments can be a very challenging task.

In all these, it has been able to play its role towards the contribution of income for the Motorola Group as a whole.

2.2.1.2 Background to Research Survey

Motorola KLM uses a number of computerised production systems to assist them in its daily production process. Strategic and business planning is done in its headquarter in the United States. KLM carries out production orders given by the head office but plans its daily operations according to those orders. Its operations include the planning of the production of the required products from start to end and production activity control. The systems used are Demand Driven Production Requirements (DDPR), Back End Scheduling Tool (BEST), Tracking System for work-in-progress – wip (TRAK), Production Yield System (GENESIS), Computer Assisted Scheduling Tool-Master Production Scheduling Tool (CAST-MPS), which are the more common tools used in production.

A field study was done on the different computerized production systems used at the various stages of production such as planning, scheduling, assembling, capacity planning, work-in-process control and monitoring production yield to quality control. A survey was conducted through the use of questionnaires included in Appendix I, which consist of multiple choice questions, true or false questions, and opinions were asked about their present systems used in their daily production work.

2.2.1.3 Survey Approached

About 150 copies of sample questions related to production planning activities were distributed to a few categories of staff involved mainly in production planning. From the total amount of sample questionnaires given, about 40 samples of questionnaires were returned from among three categories of staff, mainly managers, planners and supervisors who are directly or indirectly involved with the planning functions of the entire plant production. Planners form 58.3% of the total samples followed by supervisors 22.2% and planning managers 13.9% and the rest are administrators. About half of the respondents make use of the Demand Driven Production Requirements DDPR while a small percentage 27.8% makes use of TRAK (system showing work-in-process) and 13.9% on GENESIS (system showing production yield) mainly in planning and manufacturing category of work. The chart given in Figure 2.2 shows the breakdown of the total samples taken from these three categories of workers.

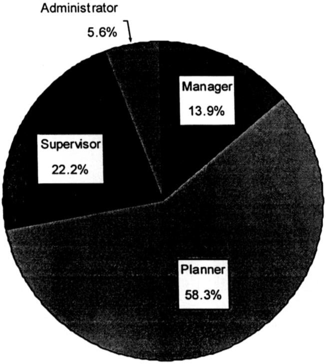


Figure 2.2 Categories of Motorola Semiconductor staff involved in the survey

The graph given in Figure 2.3 shows the number of users, from 40 samples using the respective systems in production. Although the users do refer to other systems from time to time, most were confined to just one system because of their work specialisation. Out of the 40 users, 18 of them specialised in production planning while the rest are involved in planning and administrative, and yet others oversee some assembly functions related to planning.

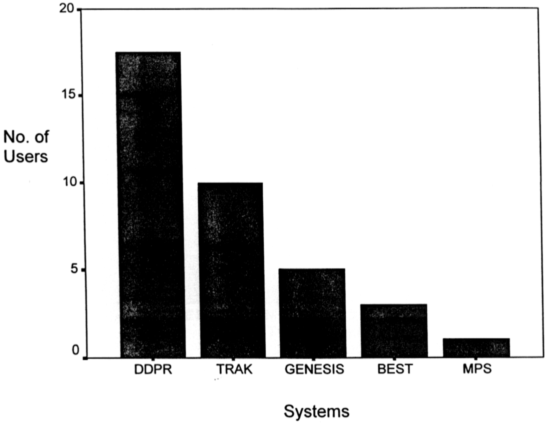


Figure 2.3 Graph showing number of users (from 40 samples) using the respective systems in production

The graph given in Figure 2.4 shows the number of users converted into percentage, using the respective systems in production. The highest is 44.4% that are using the demand driven production requirement (DDPR) system to help them in their weekly planning, followed by TRAK system, i.e. 27.8% which tracks the work-in-process that controls production activity so that it is in line with what has been planned and scheduled.

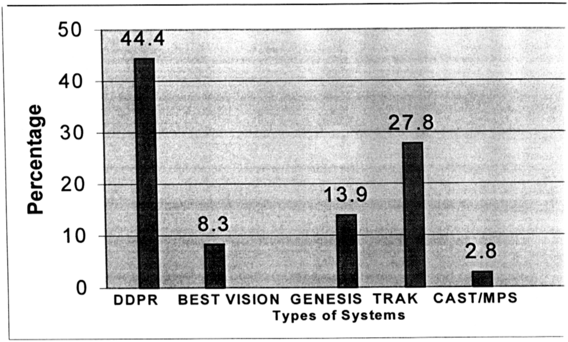


Figure 2.4 Graph showing percentage of staff using the respective systems in production

2.2.1.4 Survey Results and Analysis

From the survey results, the majority of the respondents noted that they were given formal training in using the systems while about 22% indicated that they learned from their work colleagues. The survey showed that the present system has good security features, useful to the related area of work and easy to use since the information needed is easily retrievable. However, it is found that the data in the system is not always accurate and the information in the system is also not always up to date. The majority of the respondents surveyed showed that information is scattered all over in different systems making it tedious and time consuming to look for information wanted for their daily work. In addition, they are not always able to find information needed in their work thus making the system rather unreliable.

About 42% (highest among other options) agreed that the forecasted orders are between 80-90% accurate, thus there is about 10% variance of fluctuations between planned and actual orders. However, half the number of respondents sited that the main reasons why the planned order goes out of schedule is because the plans keep changing and there is also the delay in arrival of production materials. Since these will result in delayed orders, 33.3% suggested that the best way to overcome this problem is to increase capacity and another 33.3% suggested to reschedule cycle time. Figure 2.5 shows the suggestions to overcome delayed orders and reduce backlog.

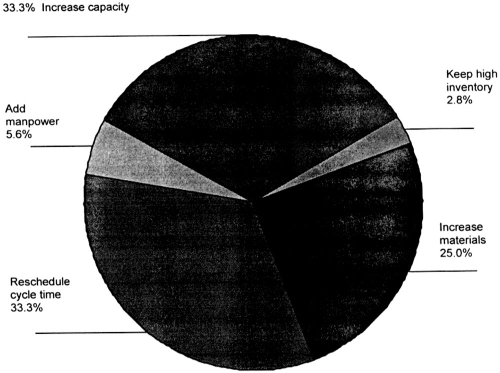


Figure 2.5 Pie chart showing suggestions to overcome delayed orders.

The majority agreed that demand orders are always delivered between 90-95% on time according to plan. Any excess orders will then be netted off into the DDPR for replanning. Although 80.6% indicated that the system is aimed at improving on time delivery and 72% cited that the system helps to reduce inventory by monitoring excess production, more than half the samples showed that the present system is unable to give them an overview into the work-in-process (wip) so as to help them monitor its progress and watch out for potential pitfalls. Besides, the respondents who are mainly planners, are unable to make changes to their scheduling when production has already started thus any adjustments must be made manually. The present system neither supports the scheduling of secondary resources such as manpower, equipment and operation hours, nor can the workers review their production resources utilisation by analysing visual load graphs in the system.

Equipment scheduling are all done manually. 72.2% of the respondents indicated that the system does not provide any window for viewing the schedule in stages so as to help them monitor closely their own respective stages of production.

In the event of production going out of schedule, the majority agreed that they are unable to select areas to block or complete in the process of production. Reshuffling of production priorities are therefore done manually. Currently the planning software is unable to model different kinds of master scheduling such as make-to-order, make-to-stock, and both. The best alternative to overcome capacity constraint, according to the survey is to add new equipment. This is the consensus of 52.8% of the respondents' opinion.

The overall production planning system is rated fair (55.6%) by the respondents as shown in Figure 2.6 and they are of the opinion that it needs a lot of fine tuning.

Figure 2.6 Rating of current planning system

The suggestions given to improve the DDPR system are :-

1) Netting of demand should be done online instead of at fixed interval in order to see actual demand quantity.
2) Improve data integrity with increase accuracy in forecasting with more reliable data. Data should also be made readily accessible for making quick decisions and make DDPR access more user friendly.
3) Improve test scheduling system to be in line with assembly scheduling.
4) Assembly and test planners should be integrated for the same product.

5) Central planning should provide linear loading instead of uneven load which causes uneven distribution that upsets the production flow.

6) Provide up-to-date, standard report for every stage of production preferably online and real-time reports for all parties concerned to view and input where needed. They can be auto-generated and printed as and when necessary.

7) Training manual and documentation related to planning to be made available to all planners for reference, especially new planners.

8) Cut down changes to plans once they are firmed up so as to reduce disruptions in production. Improve coordination and communication between planning and manufacturing group so as to enhance better teamwork between these two groups.

9) Better planning through more experienced Master Production Analyst (MPA) who has manufacturing background so as to give more accurate demand orders for execution. MPAs should be able to produce more accurate Master Production Scheduling (MPS) with least errors by using more effective rough cut capacity planning.

The suggestions given to improve the TRAK system are :-

1) Improve TRAK response time as it is slow.

2) Reduce number of TRAK screens by consolidating the number of windows to be opened when tracking lots.

3) The numbering system for tracking lots is cumbersome and needs time and memory to recall thus a better system is needed to improve on the existing one.

The suggestions given for an ideal system include :-

1) Design a system that can be used by the whole supply chain link to Motorola be it internal or external.
2) Automate all manufacturing planning functions and integrate all stages of production into one complete system.
3) The system should be able to monitor and give early warnings about production going out of schedule.
4) The system should be able to link demand to entire work in process (wip) in work area which can be viewed with a single click.
5) The system should have total control on the production process from start to finish.
6) The system should show the demand status with production shortfalls or excess in graph form that can be easily viewed and understood.
7) The system should tell those involved in the various stages of production what to do and when to do it.

2.2.1.5 Conclusion of Survey

This survey has revealed that the majority of the respondents have indicated that they would want to see improvements on the present planning system in order to help them increase their work productivity. More fine tuning is required to help make the system more efficient through automating more planning procedures and linking up the various stages of production from start to end online. A complete computerised production system will give an overview of the entire production process and activity control, and together all can work towards achieving a common goal that is meeting the factory on time delivery date (FOTD). In addition, presently data integrity and accuracy are crucial to ensure that work in progress is well monitored and not disrupted thus leading to a smoother flow in production.

Based on the observations and findings from this survey, it is of the opinion that the production planning system can be further improved by integrating the many present number of systems used in planning, into one complete production system. Although this is a very complex and mammoth task due to the nature of the large-scale production, in the long run, this will lead to total control on production activities and output, close monitoring of production falling out of schedule with a specific focus on achieving factory on time delivery FOTD besides reducing inventory. Ultimately, this can lead to a world class production status for Motorola Incorporated, which can be emulated in the face of more challenges and competition ahead within the manufacturing sector.

2.2.2 Research Analysis on Semiconductor Product Plant (Siemens/Infineon Technologies), FTZ Penang

A research study based on collected materials and literature review was done on Siemens Semiconductor plant to study how it plans its production and controls the production activities. This is to enable a comparison to be carried out between Motorola and Infineon Technologies for the purpose of finding variability among these semiconductor manufacturing companies. Ultimately, the comparison will help to enhance the development of the production planning software in accommodating commonalities and differences found in the manufacturing environment.

2.2.2.1 Company's Background

The Siemens' Semiconductor Group is a leading worldwide provider of integrated circuits, memory products, RF components and discrete and power semiconductors, sensors and fibre optic components. The comprehensive product line of Siemens' Semiconductors serves a wide range of customers active in telecommunications, automotive and consumer electronics, data processing and automation. Siemens is the market leader for Chipcard ICs.

In the fiscal year 1997/98, Siemens' Semiconductors achieved sales of $3.8 billion (DM6.7 billion) and employed 25,000 people worldwide. The Siemens' Semiconductor Group - the world's third largest optoelectronic semiconductor current business is in manufacturing light-emitting diodes, infrared components, power lasers and displays. These activities also include marketing and development in Regensburg and Cupertino, California, USA, as well as chip production in Regensburg and assembly in Malaysia.

Siemens Malaysia is the largest German company in Malaysia with a substantial entity within Malaysia's dynamic and rapidly expanding electrical and electronics market. On April 1, 1999, Siemens Semiconductors became Infineon Technologies - a younger, dynamic, more flexible company geared towards success in the competitive, ever-changing world of microelectronics. Infineon Technologies AG is a 100% subsidiary of Siemens AG in Germany. The plants are located at the Bayan Lepas Free Industrial Zone, Penang, and Malacca, Malaysia. Infineon Technologies has nearly 8,500 employees and is committed to the continuing development of Malaysia's infrastructure, offering unparalleled services, engineering support, technical advise and assistance besides developing and implementing new technologies.

Infineon Technologies in Penang specialises in lighting applications. The lamp manufacturer which is one of the three leading lamp manufacturers in the world, also has special expertise in electronic lighting systems as well as in materials such as glass and fluorescent substances, which are increasingly being used in light-emitting diodes (LED) production. Measuring only a few tenths of a millimetre, LEDs are based on semiconductor connections which convert current directly to light. Their advantages over many other light sources include lower energy consumption, an extremely long operating life of more than 100, 000 hours and very high impact resistance.

Many new applications have been found for red, yellow and green LEDs over the last thirty years, for example, in the instrument panels and third brake lights of automobiles. Moreover, researchers have succeeded not only in increasing the brightness of coloured LEDs, but also in generating blue and, most notably, white light. This opens up new market opportunities for this light source in the areas of general-purpose lighting, traffic and railway signals, and illuminated displays and signs.

2.2.2.2 Operating Procedure

The company uses a computerised system known as SYSTEM 21, which is integrated into their SAP system that covers broad areas like production, finance, inventory, procurement and other logistics. System 21 contains Production Master Data (PMT), which is a single, shared data structure to integrate materials planning and production control management. The Production Master enables high-level sub-assembly planning and management of products which are highly demanded by customers. Another benefit of this PMT is that it is flexible in responding to customers' new and changing orders. The reasons for this flexibility are that :

- the planners are responsible for maintaining production master data and their bill of materials required for production. There is no centralised buying as the group of planners are responsible for their respective work centers.
- maintenance of PMT is performed and controlled based on a Change Control Checklist (CCCL) procedures.
- planners are responsible for maintaining routing information and for updating new manufacturing throughput times as needed.

The PMT is governed by a list of maintenance policies which are strictly enforced and must be closely followed. These policies ensure that :

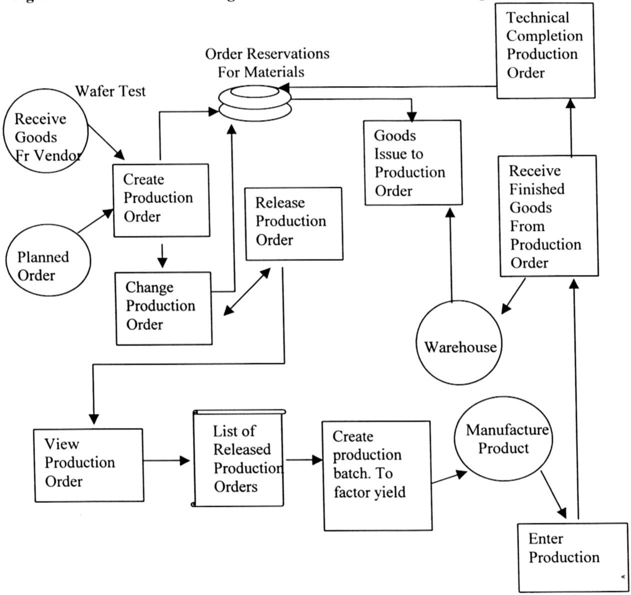
- planners must get approval from Planning Managers before making changes in PMT.
- Planners are responsible for maintaining yields as part of PMT maintenance to ensure accurate materials requirement planning or MRP calculations.

In the next section, a workflow chart will be shown and explanation given on the operations of the production planning and control using the PMT system.

2.2.3 A Comparison of Workflows

This section will show a comparison of workflows between Infineon Technologies and Motorola KLM. This will give a better understanding to the operating procedures and their respective production functions of the two semiconductor companies as well as the differences between them. Figure 2.7 explains the production planning and control of Infineon Technologies. It is a workflow to show the company's operations from start to end.

Figure 2.7 Production Planning and Control for Infineon Technologies

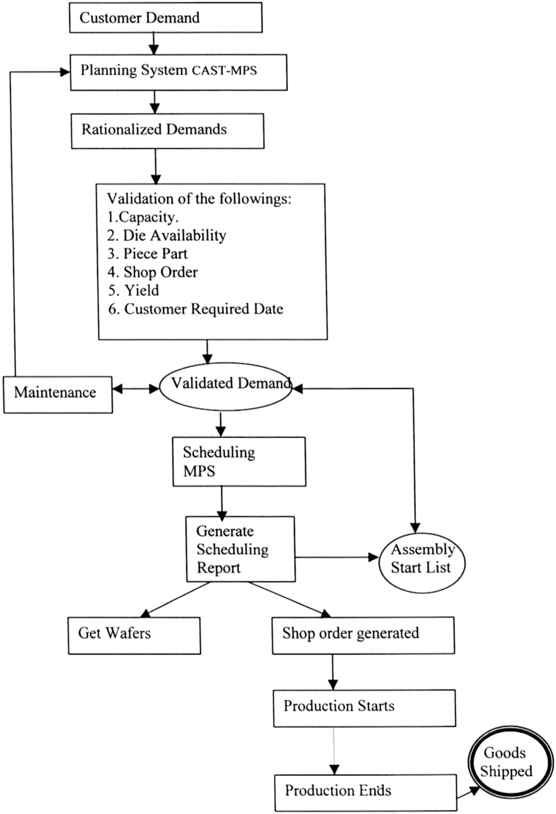


The workflow shows that production starts with the creation of production order with inputs from the planned order and the availability of wafer (used for integrated circuits or ICs) as this is a main component used. The production order can be changed depending on whether there is enough capacity and materials. Then a list of production orders is released when there is sufficient capacity and required raw materials, followed by scheduling which is done by creating production batches in the workstream.

The manufacturing of product takes place as the production batches enter the workstream. In the mean time, production materials are issued according to production order. The finished goods are then sent to the warehouse after all quality tests have been carried out. Goods are then delivered from the warehouse to the customer accordingly.
This workflow shows that whatever changes to the production order are done in the initial stage of planning. This is very important because once production begins, changes cannot be accommodated in the midst of production. Any change to the production plan when production is in process will be deemed as production loss to the plant if the goods are not wanted by customers.

Next, we look at the workflow of another semiconductor plant. Figure 2.8 explains the production planning and control of Motorola KLM. It is a workflow to show the company's operations in summary.

Figure 2.8 Production Planning and Control for Motorola KLM



The production flow of Motorola KLM begins with the customer demand which is netted into the planning system known as CAST-MPS. This demand is then rationalised or validated against capacity, die (ICs) availability, piece parts (circuit boards), shop order, yield and the customer's required date. Once these are validated, scheduling can be prepared and a report generated. When ready, a list of the production schedule is sent to the assembly line for standby production. If demand cannot be validated, then it has to be routed back into the planning system for replanning. When the scheduling report is generated, the planners must ensure the availability of wafer, and at the same time, generate a shop order for production to kick off. Production here is done in lots. Once begin, the work-in-process counted by the number of lots goes through the production process until they are completed and the goods are delivered directly to their customers all over the world or to their regional offices if requested.

These two workflows show that production planning is a very crucial in determining a plant's production rate. A proper and accurate planning with a correct lead time will determine the rate of success for manufacturing companies besides having good demands for the manufactured products. Production planning, master scheduling and shop floor control are three key factors that will enable production companies to survive the ever changing and demanding patterns of her customers. Therefore an effective and accurate computerised production planning system is indeed needed by every manufacturing company and the aim of this research is to develop a customisable production planning and control system that will take into account the specifics of the manufacturing environment when designing and implementing this system.

2.2.4 Conclusion of Initial Research Activities

The two initial research activities, namely through field study and survey as well as through literature review, particularly of the two companies, have helped to contribute towards the learning curve of the whole manufacturing industry and its activities.

The former method of field study has given direct exposure to enrich our learning experience as it is always easier to learn and master a trade with on the job training. The knowledge gained through direct contact with people who are directly involved in the area of production planning has helped us understand the manufacturing environment and its operations in real life. This approach has certainly hasten the learning capacity and reduces the learning time required to master the skill of managing production.

The second research activity which is through literature review, is enhanced by the first method. It is easier to understand books written about production with a background knowledge accumulated through field learning via the first activity. Books and literature in manufacturing domain have contributed in getting additional knowledge about the diversities of production, and thus enhance what has been learned in the manufacturing plant. The knowledge gained through these research activities will be the foundation for the development and the design of a customisable production planning tool. With the understanding acquired about production planning and the analysis completed, the next phase involves the development process of an object-oriented planning tool that will encompass all the details learned about production planning and control. The following chapters will see the object-oriented software engineering process and development of the production system through to implementation and testing which in short, is the system development life cycle based on object-oriented technology.

2.3 Existing Research Prototypes and Techniques

Object-oriented techniques that are commonly used in the development of manufacturing prototypes include :-

i. Object Modeling Technique (OMT), developed by Rumbaugh et al., 1991. OMT which covers both the analysis and design phases of the development life cycle combines object-oriented concepts with information modeling concepts that include entities and associations. This technique is driven by the creation of a set of analysis models namely, the object model, the dynamic model and the functional model which first characterised the processing requirements for a proposed system. Once the analysis models form the basis for the system to be implemented, they are then used to design the frameworks, architecture and design strategies required for developing the system.

ii. Object-Oriented Software Engineering (OOSE), also known as Objectory process by Jacobson, 1992.

The Objectory process is driven by the use case modelling concept. A set of use cases that define all system behaviours is elaborated to a fully traceable design that is implemented through staged incremental development. This method encompasses analysis and design and it works with five different models, the requirements model that captures functional requirements, the analysis model that emphasises on developing a sound extensible object structure, the design model that refines the object structure to suit the implementation environment, the implementation model that is used to implement the system and the test model that is to verify the system. The use cases are modelled according to the system's requirements and are remodelled when there are changes in the system behaviour. Through the use cases, the whole system architecture is controlled by what the users wish to do with the system.

iii. Booch Object-Oriented Method, by Grady Booch, 1991.

The Booch method which is most applicable to the design of real-time systems, covers the analysis and design phases of an object-oriented system. Booch supports the iterative and incremental development of a system. This method is rich in symbols and graphical notation as well as supports classes, objects, inheritance, message passing and polymorphism. The static model is separated from the dynamic model in the system design. In the static model, it shows the architecture that is represented by the class diagram. The object diagram shows how the classes interact with each other, by capturing some moments in the life of the system through state transition diagrams and thus helps to describe the dynamic behaviour in the dynamic model. Booch also separates the logical and physical designs of a system: the logical design involves class and object structure while the physical design involves module and process architectures. In the Booch process, software development occurs through the iterative interplay of macro and micro processes.

The Macro process establishes core requirements (conceptualisation), develop a model of the desired behaviour (analysis), create an architecture (design), evolve the implementation (evolution) and manage post delivery evolution (maintenance). The Micro process identifies the classes and objects at a given level of abstraction, identifies the semantics of these classes and objects, the relationships among these classes and objects, specify the interface and then the implementation of these classes and objects.

iv. Object-Oriented Systems by Shlaer and Mellor, 1988, 1992.

This method is typically associated with real-time, multi-tasking systems that use an object-oriented approach for doing structured analysis and design. It consists of three steps: the information model; the state model and the process model. The information model identifies the entities in the problem domain in terms of objects, attributes and relationships. The state model expresses the life cycle of each class object and generates an event table from the state model. A given event in a particular state causes a prescribed action to take place. This leads to the creation of an Action Data Flow Diagram (DFD) using the process model to define action lists in the state model. At this stage, the analysis is completed and design begins with a much more object-oriented nature that includes the distinction between classes and objects, inheritance and polymorphism. The main design diagrams include class diagrams, class structured charts, dependency diagrams and inheritance diagrams.

v. Object-oriented Analysis and Design by Coad & Yourdon, 1991a, 1991b.

The Coad &Yourdon method is a relatively simple approach to object-oriented analysis and design. This technique is one of OO analysis resulting from a merger of information modelling, object-orientation programming languages and knowledge-based systems (KBS), which are the concepts used to manage complexity. The process can be summarised as follows: finding object classes to describe the problem domain using class-&-object diagrams, then identifying structures which are shown as generalisation-specialisation diagrams and whole-part structure diagrams. This leads to the identification of subjects which is a way of segmenting a problem and creating a boundary between groups of closely related classes and creating parts of the model into subdiagrams. The next layer is to define attributes and operations of classes and their instances. The output of this stage is the attribute diagrams and instance connection diagrams. The final layer is the service layer to show interactions between class operations using an object model with specified services and message connections between them. The results from this service stage are service diagrams, message connection diagrams and object state diagrams.

vi. Unified Modelling Technique (UML) by Booch, Jacobson, and Rumbaugh, 1992

The Unified Modeling Language™ (UML) is the industry-standard language for specifying, visualizing, constructing, and documenting the artifacts of software systems. It simplifies the complex process of software design, making a "blueprint" for construction. The UML was created by the joint efforts of leading object technologists Grady Booch, Ivar Jacobson, and James Rumbaugh with contributions from many others in the object community represents one of the most significant developments in object technology. Supported by a broad base of industry leading companies, the UML merges the best of the notations used by the three most popular analysis and design methodologies, Booch, OOSE (Use Cases), and OMT, to produce a single, universal modeling language that can be used with any method of system development.

Some of the prototypes which used the above techniques include OSCAR, the Object-oriented SCene AnimatoR, led by Rumbaugh [Rumbaugh et al., 1991], that produces high quality film and video sequences of the results of scientific and engineering calculations and experiments which started in 1984, focuses on the application of object-oriented technology to industrial applications. The AXE system, which was a new generation of switching systems, was developed at Ericsson in the midst 1970s by using the OOSE techniques by Jacobson (Jacobson et al., 1997, p. vii). Another object-oriented software application that used Yourdon's technique to manufacture hardware for satellite communications systems was developed by Satellites International Ltd. England [Wilkie, 1992].

Object-oriented development have been widely used in internal applications at the General Electric Research and Development Center (GE R&D), for developing compilers, graphics, user interfaces, databases [Blaha-89], CAD systems, simulations and control systems [Rumbaugh et al., 1991]. Some of the more recent applications that used object-oriented techniques include :

- The Australian application partner TrakHealth, which is introducing its hospital and laboratory information systems MedTrak and LabTrak to the German market at CeBIT in Germany.

- The application partner Lib-IT, with LIBERO and NetVue, a new kind of software for image reproduction in online catalogues for libraries.

- The application partner Intraprend, with new functions for the Internet-based inventory management and production planning system WWS/PPS Manager.
- The application partner Siteforum Europe, with its portal management suite Siteforum Interactive Business Portals. The new version introduced at CeBIT supports CACHÉ as its high-performance database platform.
- The consulting partner Synerva, with a variety of CACHÉ projects - including a Java application that uses CACHÉ for the persistent storage of its object data model.
- Reuse Process Manager (RPM) by Extended Intelligence, Incorporated, which is a process manager tool enabling corporations, software projects and individuals to practice software reuse. RPM is a user-friendly windows-based environment integrating reuse-based methodologies, tools, examples and project management.

2.3.1 Reuse Techniques for Customisation

Some of the reuse techniques used for implementing customisable features include specialisation techniques, which is a form of <<generalisation>> that refers to the variability mechanisms [Jacobson et al., 1992; Griss, 1995d]. Abstract componets can be specialised using a wide range of generalisation and specialisation techniques. These variability mechanisms include :

- *inheritance* which is used to specialised and add selected operations, while keeping the rest

- *extensions* which are small type-like attachments that can be used to express variants attached at variation points in use case and object components
- *uses* which is reusing an abstract use case to create a specialised use case
- *parameters* which are several small variation points for each variable feature
- *generation* of derived components and various relationships from languages and templates. The generator is often a conversational or language-driven tool.

These variability mechanisms provide a powerful way of making components more generic, thus enhancing reusability for future enhancement [Jacobson et al., 1997].