3. THE EVOLUTION OF MES

"Even before manufacturing execution systems (MES) became a defined category of industrial software used to control manufacturing operations, many manufacturers had been using some form of MES either manually or by computer point solution."
(Hakason,1996:26)

Factors, which influence the evolution of MES, are categorized (for purposes of this investigation) as follow:

1. Manufacturing strategy
2. Manufacturing Planning and Control Systems
3. Information Technology

Trends within these categories are indicated on the same time scale in *Figure 10*. In this chapter each of these areas is discussed accordingly.

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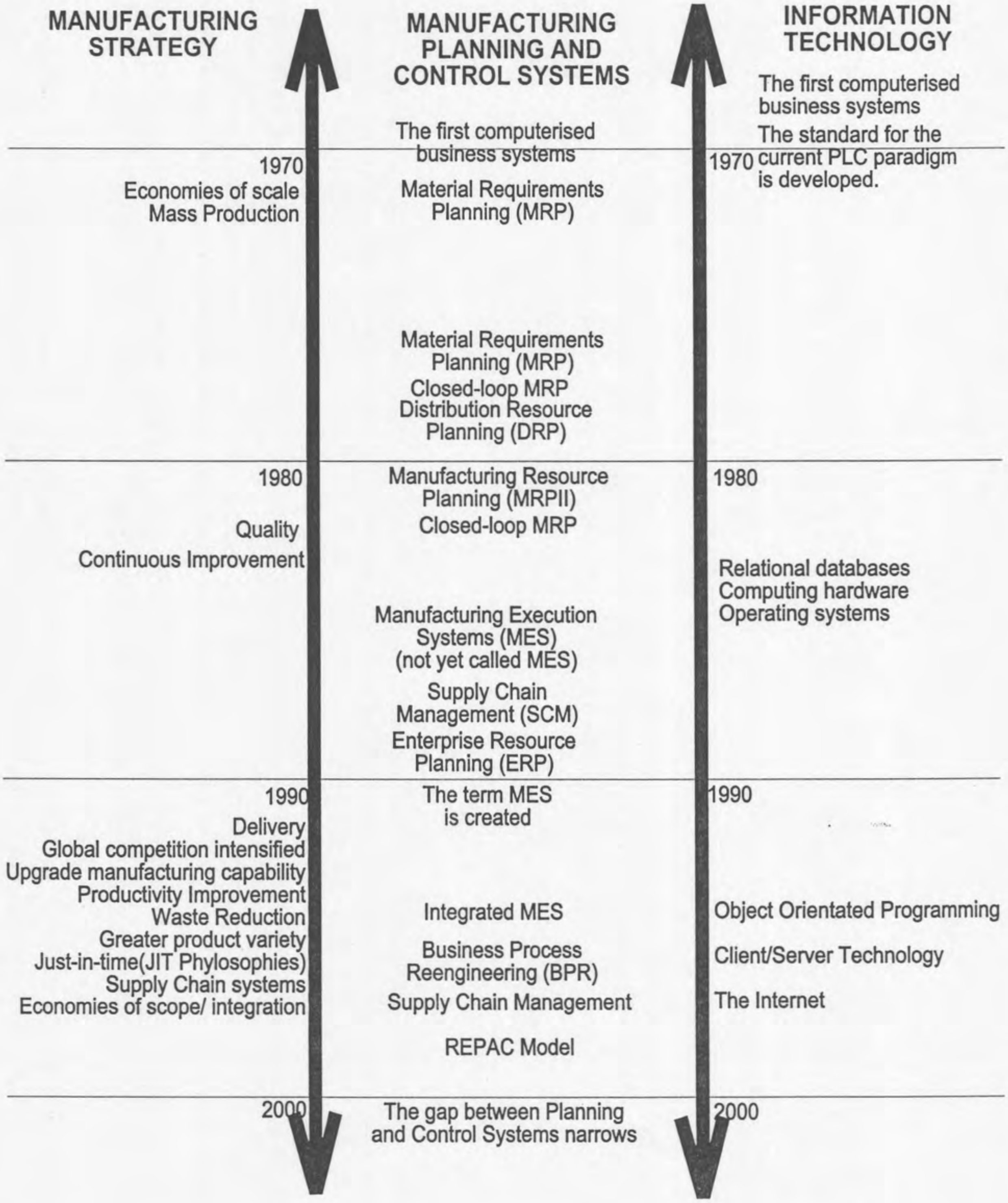
Figure 10

The evolution of concepts related to MES



3. 1. THE EVOLUTION OF MANUFACTURING STRATEGY

"Despite advances in manufacturing and computer software technologies, most manufacturers are basically managing their shop floor activities the same way they were twenty years ago. If you visited the computer rooms or looked over a planner shoulder, you'd find dated computer systems and timeworn management strategies, which simply don't fit the new realities of global manufacturing."

(MESA International,1997:www.MESA.org/html/main.cgi?sub=32)

Table 5 is an extract from a figure drawn by Chase (1998:41). MES can be positioned as an information technology based solutions to accomplish business integration, agile manufacturing and flexibility.

Table 5

Evolving Management Perspectives

	1920 – 1980s	**1980 - 1990**	**1990 - 1995**	**1995 - 2000**	**2000 & beyond**
	Mass production	**Lean production**	**Agile manu-facturin**	**Agile manu-facturin**	**Strategic agility**
Competitive priorities	Cost	Quality	Delivery	Flexibility	Knowledge factory
Process criteria	Scale efficiencies	Continuous improvement	Time/ quick response	Economies of scope/ integration	Mass personalizatio n/ economies of knowledge
Source of value added	Capital/ muscle power	Local infor systems/ work teams	Supply chain systems/ cross functional teams	IT enabled processes. Process expertise & relationships.	Intelligent systems/ communities of practice

According to Willis (1998:83), the dominant theme from the 1950s and into the 1970s was economies of scale using mass production. Large facilities built to produce huge quantities of goods required complex organizational structures for sufficient management and control. Conventional wisdom at the time dictated that low unit cost was achieved by spreading fixed costs over the largest possible volume of output. Quality was the dominant theme by the 1980s as US manufacturers were pressured to match the higher quality offerings of foreign producers. Statistical process control (SPC), employee involvement in quality assurance programs, and improved product design were key elements of quality improvement. Globalization (in the late 1980s and early 1990s) necessitated the upgrade of manufacturing capability.

3. 1.1. GLOBAL COMPETITION

The emphasis was placed on continuous improvement and waste reduction (as part of the JIT / TQM philosophies). More effective planning and control were required from planning systems, such as manufacturing resource planning (MRP II).

To survive companies have to adapt to rapidly changing markets. More suppliers are competing for the same customers with high quality, reasonably priced products. As part of the JIT philosophy, the emphasis has shifted towards partnerships with customers and suppliers. Since customers require more and more flexibility, manufacturers have to produce exactly what the customer wants, in a fraction of the time and at a fraction of the cost of the old methods. To be responsive and adaptive, organizations need to focus on the processes required to meet specific customer demands. (MESA International,1996:www.MESA.org/html/main.cgi?sub=32)

3. 1.2. AGILE MANUFACTURING

Flexibility, speed, and responsiveness to the customer are increasingly recognized as the critical order-winning criteria (and even order-qualifying criteria) for competing in the restructured markets. Agile manufacturing seems to be the solution to meeting customer demands for products in less time at lower costs.

Matthews (1996:www.atp.nist.gov/www/comps/briefs/95120024.htm) explains that lean production entails the enhancement of the mass-production (repetitive manufacturing) process, on the one hand, as well as the production of highly customized products, on the other hand:

- In the first instance, the elimination of inventory, defects, waiting and other forms of waste have shorter lead times, improved quality, and a higher level of customer service as result.

- Highly customized products are produced in an attempt to satisfy a wider spectrum of customers.

Lean production refer thus to the ability to deliver the right quantity of a unique product to the customer when and where required - all for a price equal to mass production conditions.

(Matthews, 1996:www.atp.nist.gov/www/comps/briefs/95120024.htm) continuos by arguing the agile manufacturing is a key to success, in particular for small and medium-sized companies, competing against lower-cost products from foreign producers. The weekly - or even monthly - batch generated production plans are not acceptable in the lean production environment. MES enable real-time (or near real-time) reaction to these plans and contribute accordingly to the lean production ability.

3. 1.3. CONCLUSION

- It does not come as a surprise that the term MES, MES definitions, business models and functional definitions are created and developed concurrent with manufacturing strategies.
- Valstar (1998:www.valstar.co.uk/MES/index.htm) remarks that because agile manufacturing became imperative in the fast-changing, global competitive environment, manufacturers increasingly make use of MES to improve the ability to respond to change.
- According to MacDonald (1998:www.consilium.com/Publications/roi.htm) manufacturers adopt integrated MES software packages for the same reason they turned to MRP II in the 1970s, namely to gain competitive advantage in world markets.
- MES products were first adopted in industries with high value products, complex or unstable processing, or heavy governmental regulations (eg. semiconductor manufacturers, prime contracts in the aerospace and defense industries and makers of pharmaceuticals). MES packages are gaining wider acceptance as

industries are faced with customers demanding better delivery performance and higher levels of quality at lower cost.

As manufacturing strategies evolves, so does the systems, plan and control manufacturing - as discussed in the remainder of this chapter.

3. 2. THE EVOLUTION OF MANUFACTURING PLANNING AND CONTROL SYSTEMS

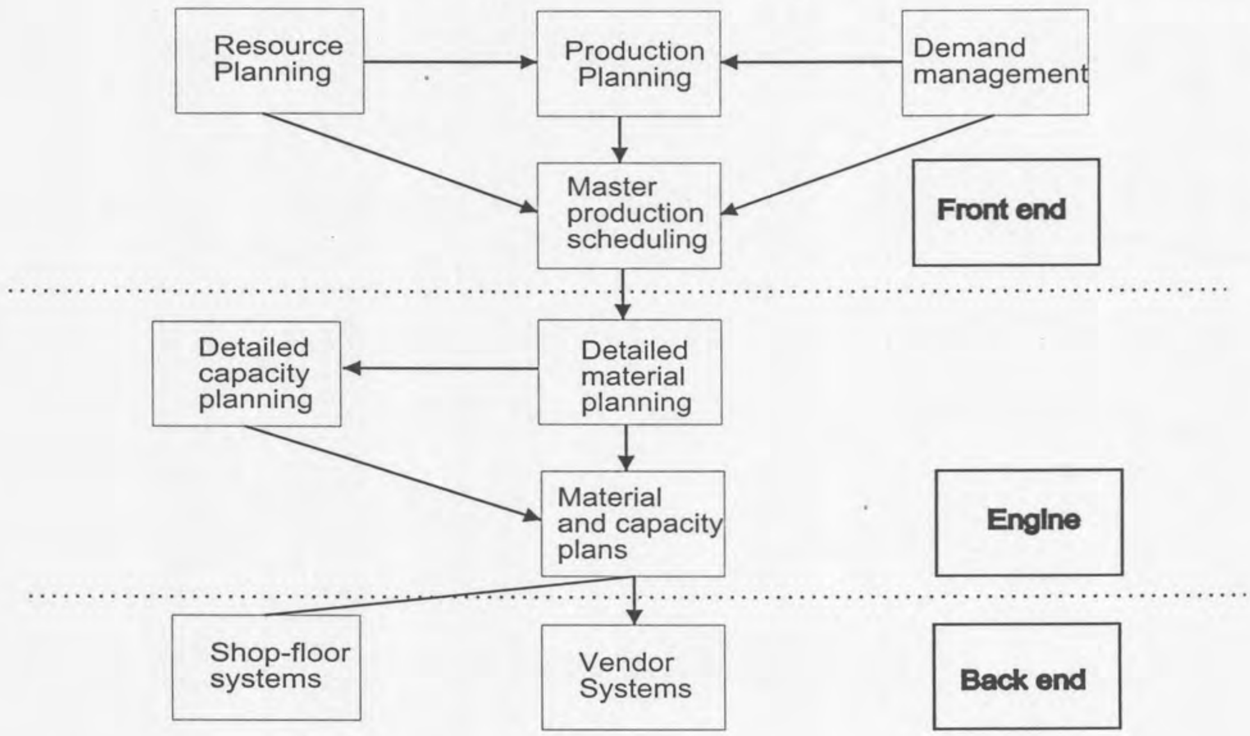
"MES applications are designed to integrate the manufacturing enterprise and empower production to play a strategic, competitive role. MES's strategic "fit" lies between corporate planning systems, like MRP II, and factory-floor equipment." (Valstar,1998:www.valstar.co.uk/MES/index.htm)

"As the information technology revolution was taking place MES grew up out of automated data collection systems, and like the evolution of MRP into MRPII, functionality was added bit by bit, until a functional critical mass established a clear point of differentiation."(Valstar,1998: www.valstar.co.uk/MES/index.htm)

Figure 11 (on the following page) indicates how the interaction of between planning and control was modeled before the term MES was created and integrated (Vollmann,1991:5).

Figure 11

Manufacturing Planning and Control model, before the creation of the term MES



Volmann (1991:4) explained this model as follow:

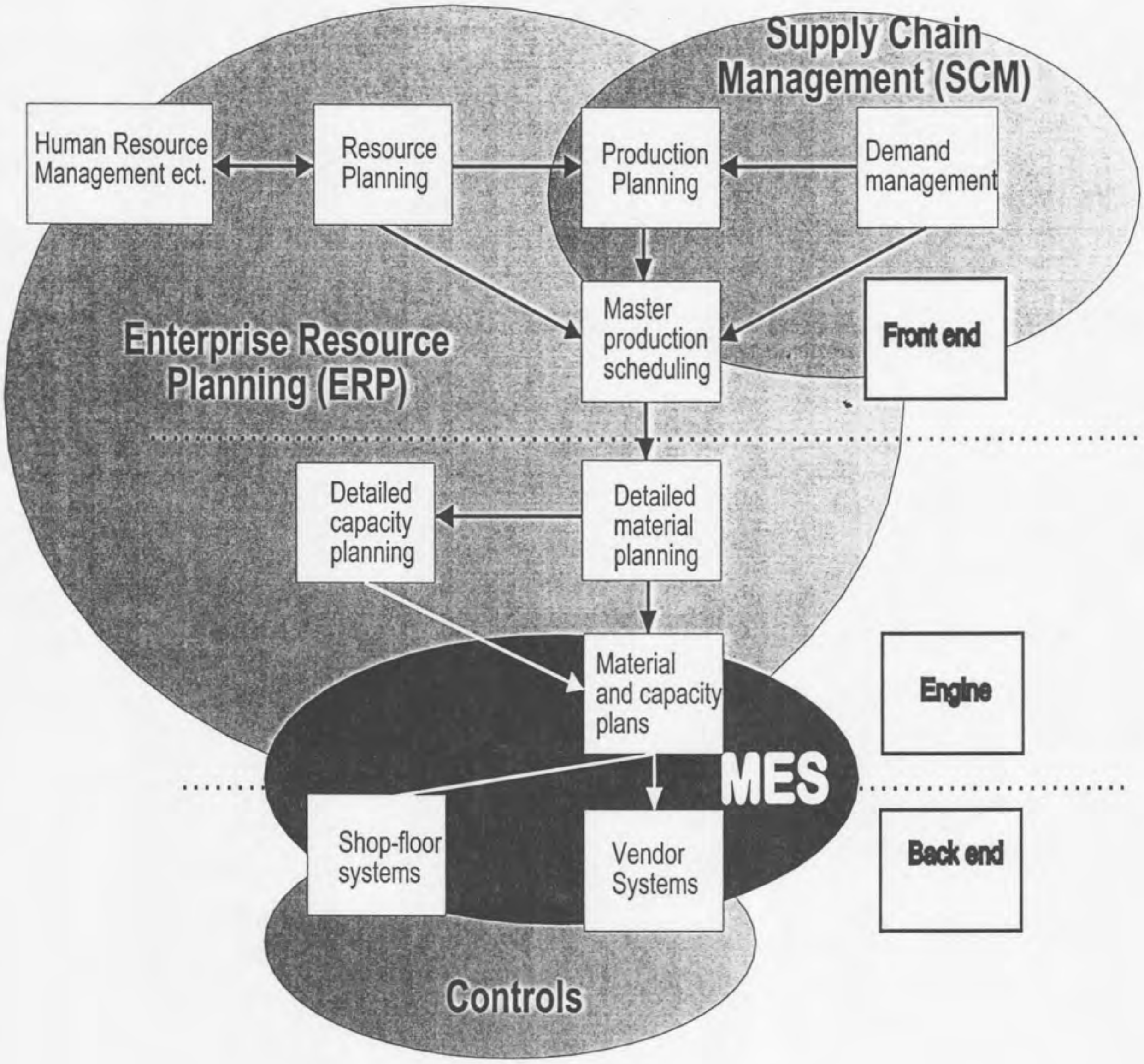
"In any firm, manufacturing planning and control encompasses three distinct aspects or phases:

1. Create the overall manufacturing plan for the manufacturing part of the company game plan.
2. Perform the detail planning of material and capacity needs to support the overall plans.
3. Execute these plans on shop floor and in purchasing."(Vollmann:1991:4)

Figure 12 illustrates the relationship between the Volmann model and the MES model from MESA International. The communication gap between the planning and control layers, as well as the lack of bottom-up communication is clear. To investigate the development of business models from the model of Volmann (*Figure 3*) to the Three-Layer-Model (*Figure 11*) the evolution of elements of these models are subsequently evaluated.

Figure 12

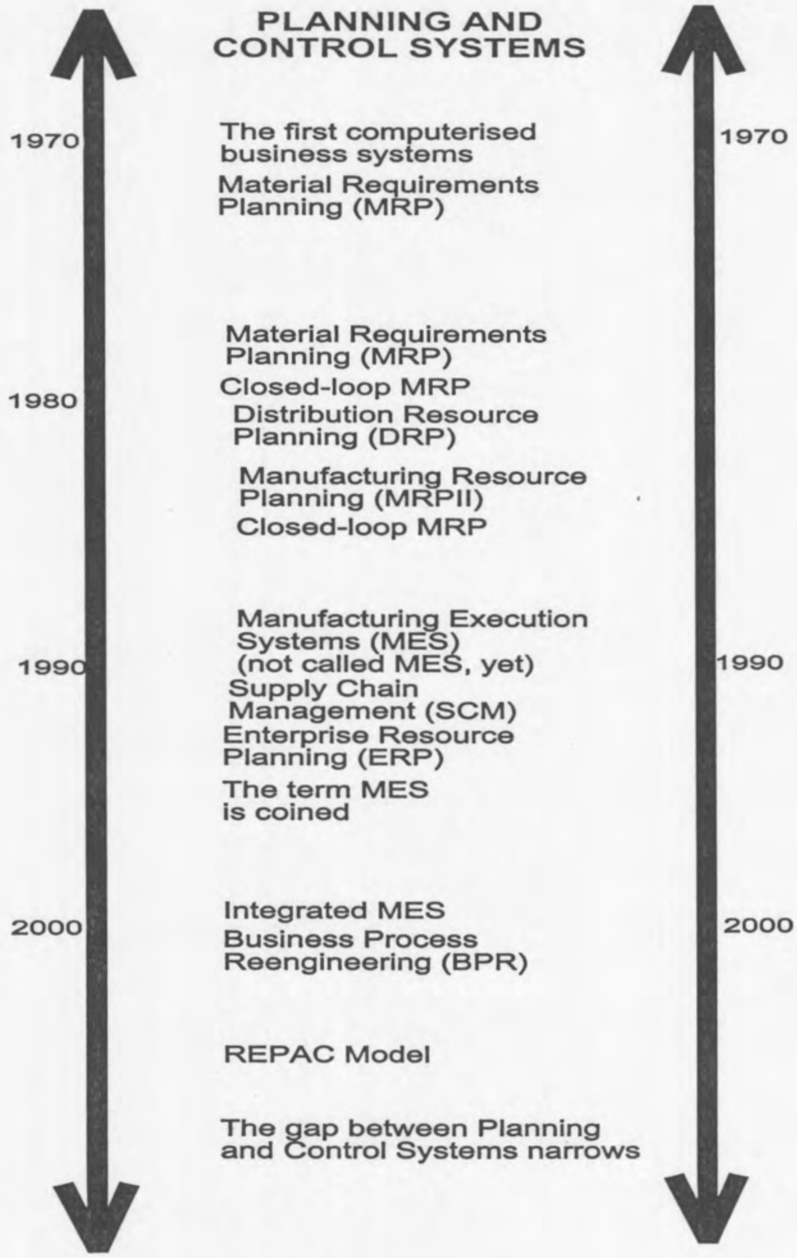
Business model before the coining of the term MES (Volmann) related to business model after the coining of MES (MESA International).



The evolution of manufacturing planning and control systems, since 1960's is illustrated in *Figure 11* on the following page. This evolution is discussed thereafter.

Figure 13

Overview on the evolution of Planning and Control Systems



1960s - 1970s

The first computerized business systems were used in accounting. By the late 1960's / early 1970's material requirements planning (MRP) evolved from these accounting systems. MRP was intended to help manufacturers better plan material availability. (MESA,1996:www.MESA.org/html/main.cgi?sub=32)

As far as the control layer is concerned, the development of Programmable Logic Controllers (PLC's) can be regarded as a milestone. Ross (Handbook,1992:1915) predicted that PLC technology will be incorporated more and more into the total control system. However, Marks,1997:www.industry.net/nmw97/MES1d.htm, draws attention to the fact that PLC technology did not develop by the same rate as computer automation in general: "The current PLC paradigm is based on a 1968 specification.The notation for programming was relay ladder logic, which was similar to electrician's notation for wiring diagrams. The PLC was the hardware platform PLC, a specialized computing device with very fast and deterministic logic solving capabilities for controlling machinery and devices in a safe and reliable fashion."

1970s – 1980s

Computers became were more powerful and capable of handling more data and being used interactively by more people. By the late 1970s and early 1980s MRPII (Manufacturing Resource Planning) evolved from MRP (Material Requirements Planning). MRPII systems have the additional ability to incorporate capacity constraints into the planning process. Other functions, such as shop floor reporting and purchasing are added to MRPII.

However, there were still business areas and processes, which were not covered by MRPII. Distributions Resource Planning (DRP) systems were developed to address the requirements in distribution, while certain shop floor solutions (such as quality control systems) emerged to manage the shop floor and react in real-time. A number of other unique, function-specific systems evolved as well. Specific business problems were solved with these systems. However, the advantage of data from other systems did not exist, since these systems were not commonly integrated.

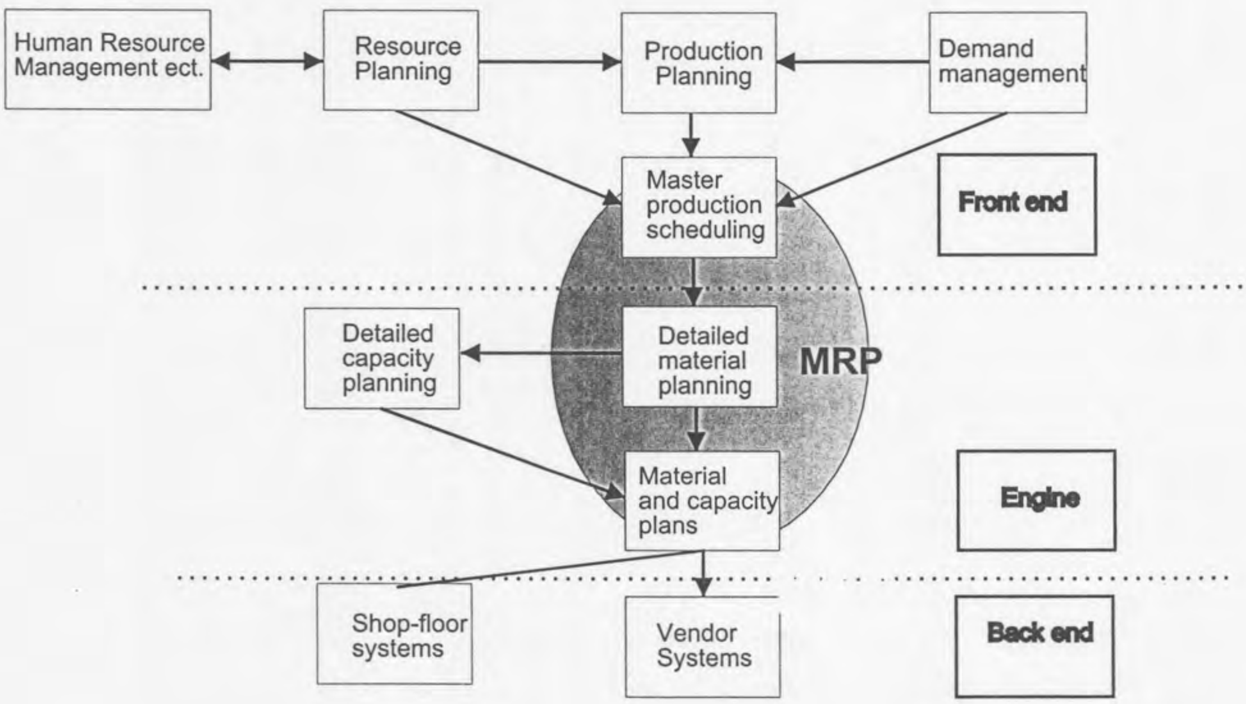
As far as the control layer is concerned, memory and processing capabilities of PLC's - as well as the number of instructions handled – by the PLC's – became more powerful. However, the software to manage and the communications between these devises did not develop at the same rate. Marks (1997:www.industry.net/nmw97/MES1d.htm) explains that the functions of control systems developed from a device control and safety perspective and not from a data management and information sharing perspective.

1980s - 1990s

In the late 1980s and early 1990s, another generation of systems became available. The aim of these systems was to establish total solution integration. (Thus solving the "islands of information problem"). Enterprise Resource Planning (ERP) developed accordingly from MRPII. Likewise Supply Chain Management developed from ERP and the shop floor solutions evolved into integrated MES. In all cases, solution-focused systems, such as quality or maintenance management, remained viable alternatives for companies which required more functionality that that available in the integrated solutions. (MESA,1996:www.MESA.org/html/main.cgi?sub=32)

3. 2.1. MATERIALS REQUIREMENTS PLANNING (MRP)

According to Vollmann (1992:15) the detailed material planning function in the engine portion. For firms preparing detailed material plans using MRP, this means taking a time-phased set of master production schedule requirements and producing a resultant schedule and material plan.



*"MRP is a set of techniques that uses bills of material data, inventory data, and the master production schedule to calculate requirements for materials. It makes recommendations to release replenishment orders for material. Further, because it is time-phased, it makes recommendations to reschedule open orders when due dates and need dates are not in phase." (APICS,1999:*www.apics.org/Dict/*)*

"MRP refers to the techniques of using a projected manufacturing productions schedule to figure out what supplied materials you will need (bills of material), and when you will need them. MRP is a simple technique, but does not take into account any constraints on the resources, or deviations from the schedule, and hence, when used in isolation can produces infeasible solutions." (Hicks,1995:14)

Chase (1995:588) explains that MRP systems determine the type and quantities of products as well as the raw material and components needed in a logical and easily understandable way. MRP also provides the time schedule specifying when each of these materials, parts, and components should be ordered or produced. The simplicity of these systems contributed to the universal installation of these systems in manufacturing companies.

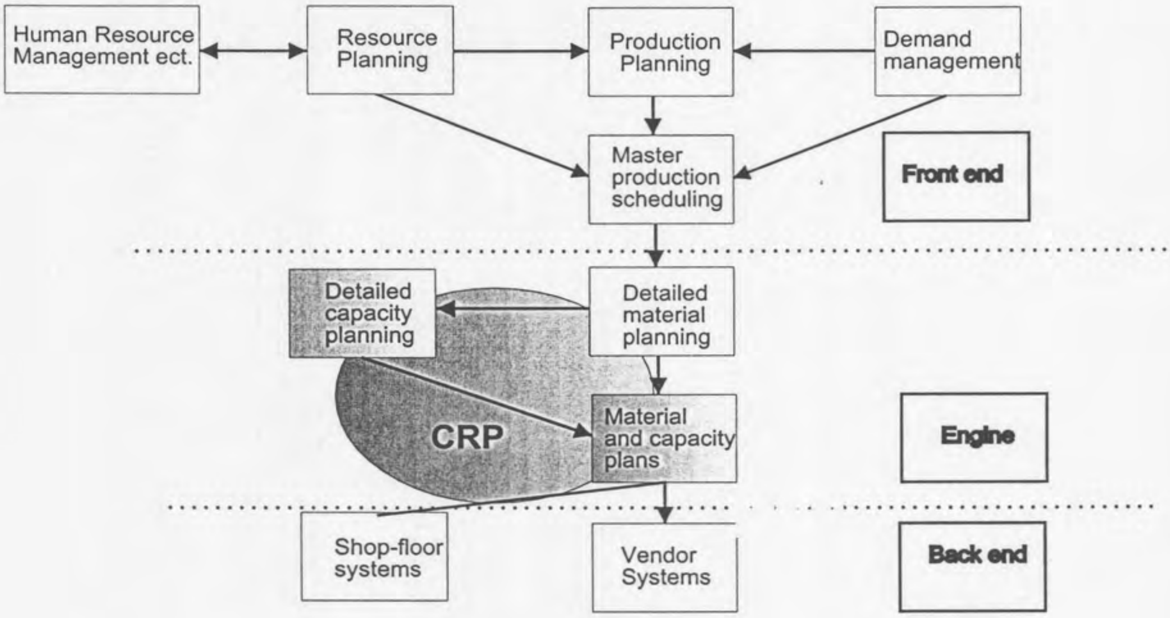
However, original MRP planned only materials. Thus, out of the original MRP systems, some enhancements were made, concurrent with advancements in Information Technology. The following functions were added gradually:

- order entry,
- forecasting,
- distribution requirements planning,
- resource requirements planning,
- master production scheduling,
- capacity requirements planning,
- shop floor control,
- purchasing and cost accounting.

When accounting and financial applications were added in the early 1980s, the name changed to MRPII to reflect these enhanced capabilities.
(Marks,1998:www.industry.net/nmw97/MES1d.htm)

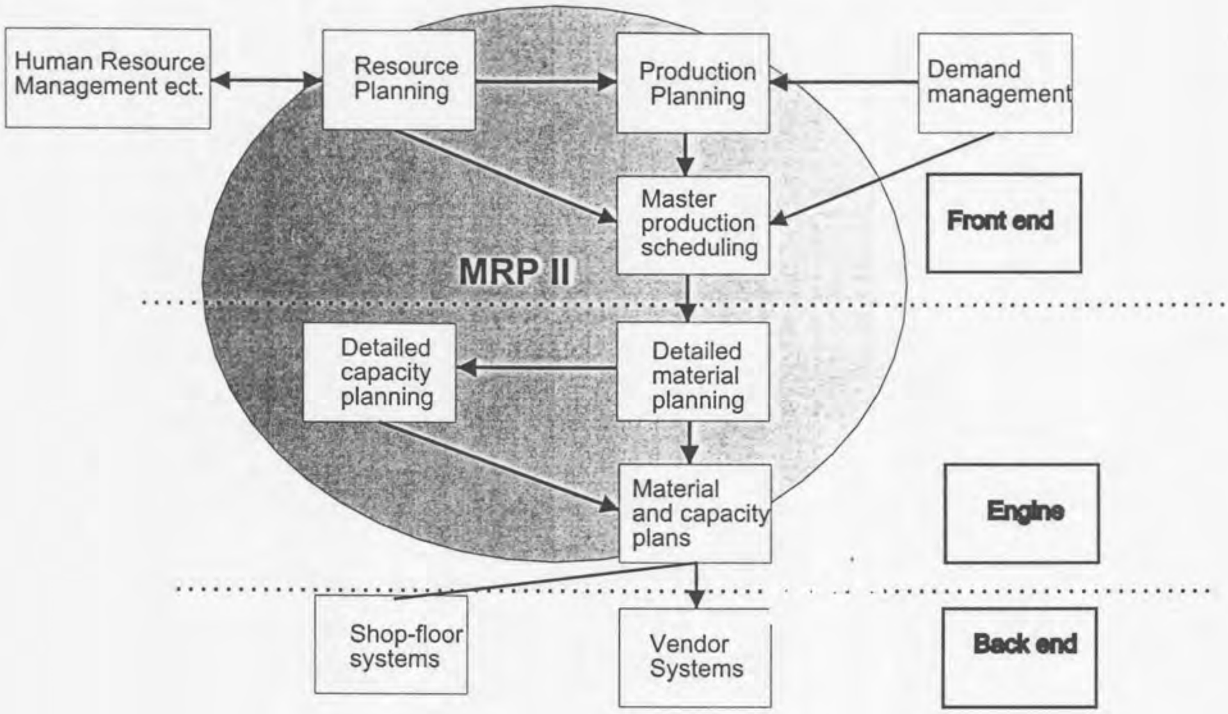
3. 2.2. CAPACITY REQUIREMENTS PLANNING (CRP)

"By tying in actual productions data and resource constraints MRPII is able to produce feasible productions plans to help stabilize and control manufacturing systems. Capacity planning tools typically perform a similar function: matching up production plans and schedules with available capacity." (Hicks,1995:14).



APICS (1999:www.apics.org/Dict/) explains that the CRP systems translates open shop floor orders and planned orders (from the MRP system) into hours of work by work centre by time period. This is done through the use of parts routings and time standards. The CRP systems may identify specific time periods of insufficient capacity, not anticipated by the rough-cut capacity plan.

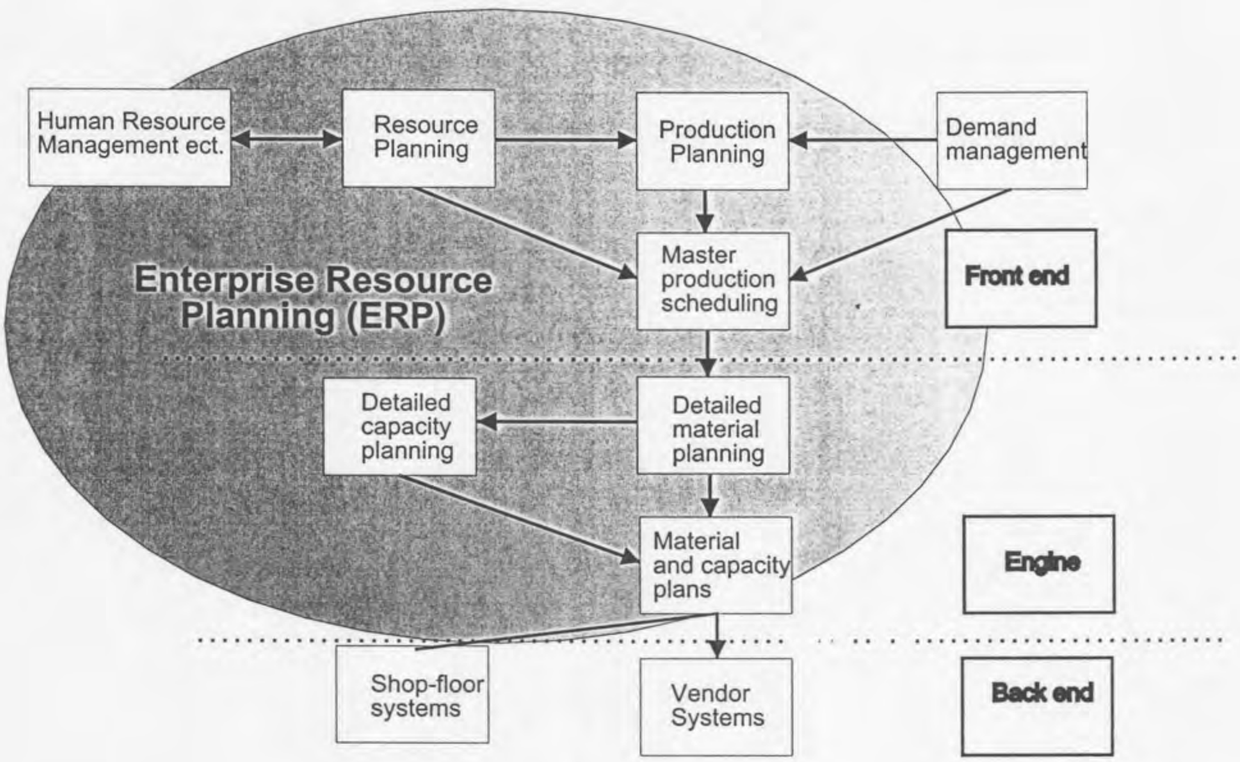
3. 2.3. MANUFACTURING RESOURCE PLANNING (MRPII)



"MRPII is a method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has a simulation capacity to answer "what if" questions. It is made up of a variety of functions, each linked together: business planning, sales and operations planning, production planning, master production scheduling, material requirements planning, capacity requirements planning, and the execution support systems for capacity and material. Output from these systems is integrated with financial reports such as the business plan, purchase commitment report, shipping budget, and inventory projections in dollars. Manufacturing resource planning is a direct outgrowth and extension of closed-loop MRP" (APICS,1999:www.apics.org/Dict/)

As shop floor control improved, attention was given to the creation of a viable master production schedule, as well as the maintenance thereof. The term "closed loop MRP " emerged as better master production scheduling was incorporated into MRP-based Manufacturing Planning and Control (MPC) systems. Additional enhancements of closed loop MRP included better capacity planning procedures at the front end, engine and back levels. It was now possible to include financial plans based on the detailed Manufacturing Planning and Control process. Simulation possibilities were added along with various ways to examine "what-if" scenarios. From this Oliver Wright coined the term Manufacturing Resource Planning (MRPII) (Vollmann,1991:15).

3. 2.4. ENTERPRISE RESOURCE PLANNING (ERP)



Controls

"Enterprise Resources Planning (ERP) consists of those systems that provide financial, order management, production and materials planning, and related functions. The modern ERP systems focuson global planning, business processes and execution across the whole enterprise (intra-enterprise systems), with an accrued recent importance of aspects like supply chain planning and the whole supply chain management aspects and extending to include the whole enter-enterprise supply chain." (Object Management Group,1998:5)

As manufacturing has grown to serve larger markets, so has the complexity of such coordination. In its current state of evolution, manufacturing resource planning requirements have been expanded to envelop the entire manufacturing enterprise. Although the enterprise requirements planning (ERP) model has succeeded in coordination of plans, it has fallen short in supporting the actual achievement of those plans. (Consilium,1998:www.consilium.com/Publications/gap.htm)

These systems include ability to manage multi-plant and multi-country operations, have preventive maintenance modules, advanced scheduling and planning, utilize expert system-based scheduling and artificial intelligence, and include enterprise logistics planning. These systems are now called enterprise resources planning (ERP) systems. (Marks,1997:www.industry.net/nmw97/MES1d.htm)

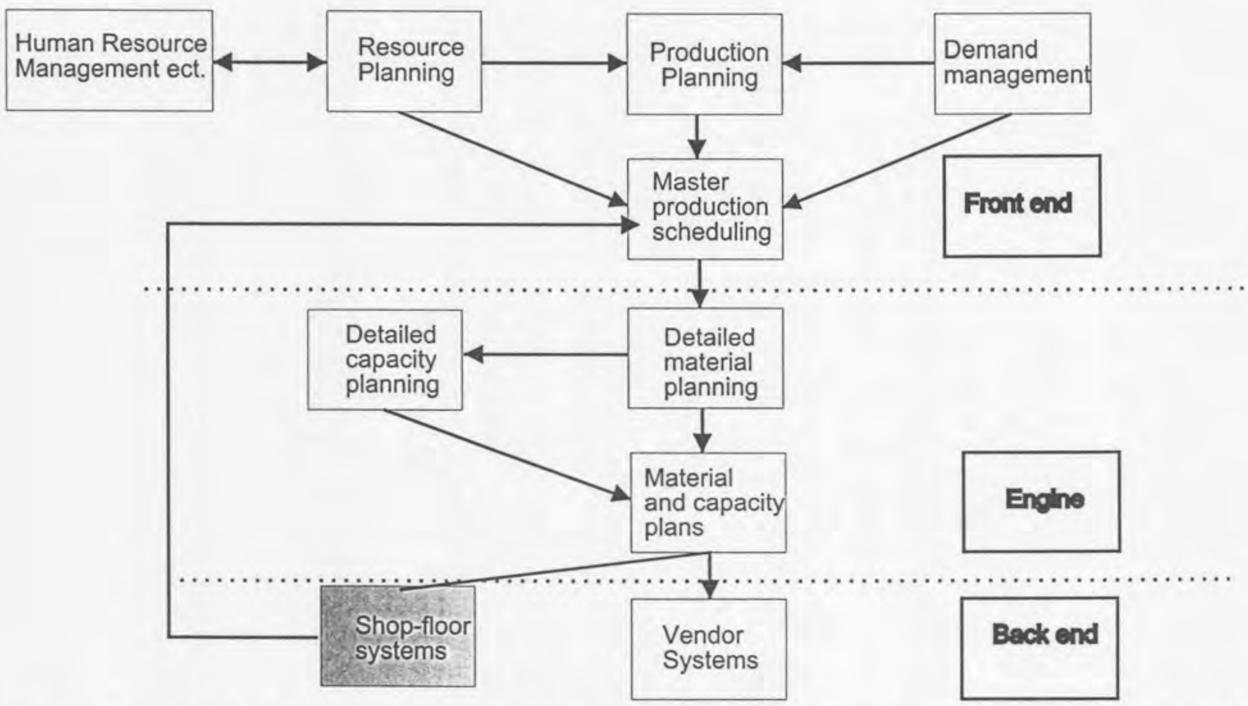
The focus and strength of MRP II or ERP is as a planning and accounting tool. Forecast inaccuracy, duality problems, capacity bottlenecks and inefficiency can undermine the best plans, leaving production scrambling. ERP doesn't make these problems visible until after they have occurred and does not provide sufficient information for correction or prevention. ERP cannot resolve these achievement gaps. Capacity, labour or overhead, and inventory must compensate for this lack of achievement. In addition, ERP does not plan overhead activity in support of manufacturing operations such as receiving, production set-up and qualification, neither for quality assurance. ERP can report that a batch of product was scrapped for inferior quality. Information regarding the cause exists completely outside the ERP planning and coordination model. Actual production configuration and processing measures are not available through ERP. (Consilium,1998:www.consilium.com/Publications/gap.htm)

Integration is the underlying foundation of successful ERP systems and is vital on several levels: ERP must transcend information technology boundaries to enable true data sharing across business disciplines; ERP must integrate with plant systems, and increasingly, ERP must integrate with advanced planning systems to achieve the decision support necessary in a world of closely linked suppliers and customers.

For manufacturers, the most urgent need is the integration of plant and ERP systems. For plant managers, the greatest benefit to be derived from extended ERP systems is the ability to generate feasible production plans that optimize manufacturing execution with customer demand. Sharing accurate data allows planners to achieve greater utilization of plant capacity and materials so that optimized manufacturing plans are created.(Mazzoni,1998: www.arcweb.com/arcsite/Search/search.asp)

The ERP system provides MES with manufacturing orders and receives status information from the MES. Other information must be shared such as part numbers, BOMs, and routings, with MES maintaining a higher level of detail than the ERP system. For example, ERP maintains a BOM for material planning, while MES maintains a detailed BOM containing all subassemblies, options and consumables for actual operation dispatching and control. An ERP routing can be limited to equipment classes or work centers for the purposes of capacity planning while the MES can maintain a much more detailed routing needed by manufacturing, equipment units, utilities, labouratories, staging areas, and maintenance. (Consilium,1998:www.consilium.com/Publications/gap.htm)

3. 2.5. PRODUCTION ACTIVITY CONTROL AND CLOSED LOOP MRP/MRPII



The function of shop floor control is to have activities performed as planned, to report on operation results, and to revise plans as required to achieve desired results. The shop floor control system also closes the control loop by measuring actual output and comparing it to plan. Thus, shop floor control systems is an essential component of closed loop MRP (Fogarty,1991:448).

Production activity control (PAC) concerns the execution of detailed material plans. It describe the planning and release of individual orders to both factory and outside vendors as well as detailed scheduling and control of individual jobs at work centers on the shop floor. Vendor scheduling is also the concern of PAC. An effective PAC system can

- reduce work-in-process inventories and lead time as well as
- improve vendor performance.

A key element of an effective PAC systems is feedback on shop and supplier's performance against plans (Volmann,1997:165).

The extension of the definition of production activity control is accentuated by the growing use of computers on the shop floor and electronic data interchange (EDI) with vendors. As more and more traditional staff work is integrated into the basic manufacturing infrastructure, it will expand PAC as well (Volmann, 1997:167).

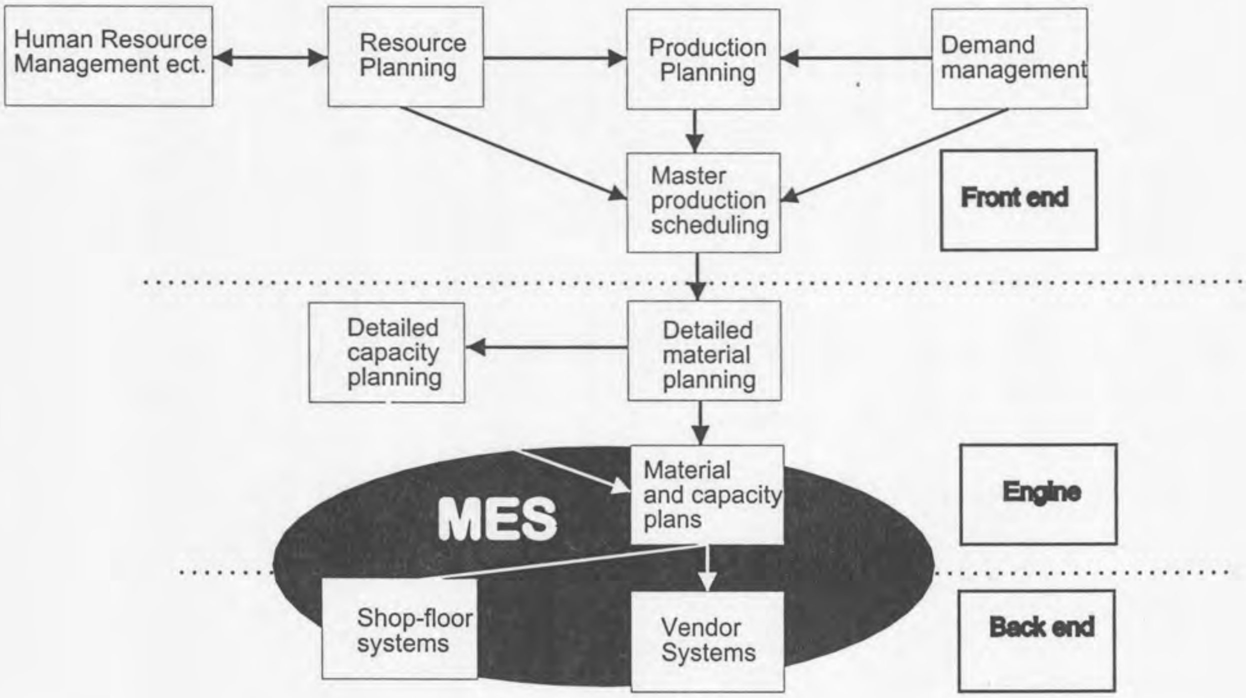
"Subsequent sophistication of MRP by adding feedback of actual results has led to closed-loop manufacturing resource planning (MRPII). Shop floor control and vendor control systems are added to the existing software so that revisions of dates and quantities will be taken into account in the next planning systems."
Degarmo,1997:1188).

The conclusion can be made that PAC is part of MES. PAC occurs, however, often in batch mode, while MES communicate with controls in real time.

3. 2.6. MES CLOSES THE LOOP IN REAL-TIME

"What ERP is to the top level of enterprise management, MES are to the intermediate level. MES concerns itself with the management of the locally owned facilities and with the coordination of centers of productivity, typically within the building. MES organizes the plant floor, tracks the plan, and as a result, improves productivity. ERP and MES, when coupled with real-time control on the factory floor (PLCs etc.), constitute the full communication and computer integration between all aspects of the enterprise."

(Morley,1998)



Close-loop MRP/ MRPII seems to be a form of manufacturing execution. Closed loop MRP/ MRPII occur, however, in batch mode, while real-time reaction is an essential characteristic of MES. The type of reaction within MES is also of much more detail than with closed-loop MRPII.

Unlike material resource planning and enterprise resource planning that enable manufacturing planning, MES technology provides a real-time window into the shop floor thereby enabling manufacturing executives to control production more effectively

and see the product as it moves toward the customer.
(Hakason,1997:www.arcweb.com/arcsite/Search/search.asp)

MRPII and ERP

McClellan (1997:12) explains that these planning systems are in principle reactive. Changes are only detected and reported. These systems react to daily plant floor changes. However, the demand for a flexible business environment, entails pre-active systems that can anticipate changes. MRPII systems were essentially designed to integrate all the operational functions of a manufacturing organization, from engineering through production, and replace a reactionary management culture with top-down planning disciplines (Martin,1995:32). The replacement of the ability to manage reactively has, however, not replace the need to react on changes. Without replacing MRPII systems, MES is integrated to business systems, to enable the necessary bottom-up reactionary management.

Manufacturing Resource Planning (MRPII) and Enterprise Resource Planning (ERP) systems were taken on as system efforts that could close the production knowledge loop. These solutions offered the promise of having production respond to delivery commitments. Reynolds (1998:81-83) explains, however, that more detailed tracking and quality information are demanded by customers. Due to the gap caused by the lack of information from the plant floor, this demand cannot be addressed. Within this new manufacturing environment real-time systems is needed to plan, schedule and execute the operations strategy effectively and efficiently. (Willis,1998:84)

Capacity planning

Through MES manufacturers can gain real-time visibility to capacity constraints. Potential capacity problems or bottlenecks can be anticipated before they occur. Shop floor and support department activities can be coordinated so they execute work assignments as a synchronized operating unit. Capacity planning should still be done by the CRP system. MES should provide the management of value-added manufacturing activities on a minute-by-minute basis. (MESA International,1996)

3. 2.7. NARROWING OF THE GAP FILLED BY MES

(a) NARROWING OF THE GAP BY THE CONTROL LAYER

The MMI/SCADA functionality is more closely tied to control strategies than MES installations. But, where MES are installed in highly automated environments, the MES must be interfaced to the MMI/SCADA application to read and write to the tag database to access data in PLC registers. In fact, developing interfaces to MMI/SCADA systems provides access to the device PLC drivers within the MMI/SCADA packages so MES vendors need not develop their own PLC drivers. When considering MES functionality, it is important to realize that the functionality is dispersed across distinct, albeit converging and blurring markets - the MMI/SCADA market and the MES market.

Many of the MMI/SCADA vendors have MES products available through their sales channel. These products can include recipe and batch management modules, discrete MES modules, and others. It is important to understand that MMI/SCADA applications do add value to MES implementations by providing a graphical view of plant-wide operations, which many MES systems today cannot provide.
(Marks,1997:www.industry.net/nmw97/MES1e.htm)

Major control companies are increasingly attempting to provide total industry solutions that may include control hardware and software, advanced control applications, material handling equipment, and production management software. Control companies are looking to enter this arena because of the potential market value of this adjoining industry. Market value is migrating away from hardware-based to software-based solutions. This is being driven by a decreasing proportion of manufacturer's capital budget spent on industrial equipment versus an increasing proportion spent on information technology (Automated Research Corporation,1998: www.arcweb.com/ARCsite/MktStudies/mktstudies.htm).

(b) NARROWING OF THE GAP BY THE PLANNING LAYER

Developers of planning systems are continuously adding MES functions to their products.

According to AIS (1999:http://www.aistech.com/workinp/workinp_wp_fm.html) changes in the Manufacturing Execution tools will be required for all ERP systems. For efficient shop floor operations the following in ERP systems are suggested by AIS and listed in *Table 6*. Many ERP vendors add similar (tradional MES) functions to their systems.

Table 6

Anticipated ERP changes

Traceability	Traceability requirements increase in a fast moving environment in keeping with the improved customer responsiveness. Almost every company needs some form of traceability whether it's the detail required by the government for medical devices production or it's the maintenance requirements of a pump manufacturer.	A preferable solution allows the enterprise to turn on Serial Control part way through the process, for historic traceability requirements. This would allow the factory to enter the serial number when the component is included in an assembly or when the finished product is received in inventory. Additionally, component traceability and the ability to relate work orders to sales orders, especially when the product cycle time exceeds one day, needs to be added. Traceability by transaction type, whereby users could select to trace by work order transaction but not by inventory move would be beneficial.
KANBAN Pull Techniques	These techniques of delivering only the goods necessary to manufacture a product when they are required means that the ERP system has to respond and coordinate this information. Triggers when the KANBAN reorder signal is issued need to inform the ERP system , which can then track and report on supplier information.	KANBAN replenishment is triggered by a signal from the shop floor. Physical replenishment will be handled by the visual signaling system. Computer tracking, via a fast and efficient interface, either code or dedicated terminal, keeps inventory and supplier information up to date. External replenishment, i.e. requesting a KANBAN from a supplier, is used to update Supplier Schedules in order to track of supplier performance.

Table 6 (continued)

Anticipated ERP changes

Supplier Schedules	Supplier Schedules in most ERP systems work well but need a lot of data maintenance to keep them current. Current Supplier Schedules functionality is not set up for Manufacturing Execution: there is too much focus on maintaining cumulative quantities to make them useful at the execution level. However, with some modification they could form the foundation of KANBAN signaling to suppliers.	Any solution needs to recognize a consumption signal that triggers the KANBAN replenishment. Supplier performance is measured by response to KANBAN signals rather than adherence to a delivery schedule. This also indicates a change in the way supplier performance is reported. The same kind of functionality could also be used to signal KANBAN replenishment between cells in a production line.
Available To Promise	The basis for calculation of ATP shifts in the Manufacturing Execution environment from a product focus to a capacity focus. Most ERP/MRP systems currently calculate ATP by product. In order for a user in a Manufacturing Execution environment to be able to promise an accurate delivery date to a customer, ATP needs to be determined by a two step process. First, the capacity availability of the environment must be determined and second, the components availability is determined.	In order to help sales team, an access window from the sales order entry module should be available. In this manner, the sales team has quick and reliable access to the ATP information as the sale order is being entered.
Product Configuration	As part of the drive to meet customer needs, product options will increase in number. Product Configuration is an important function and must respond to marketing and production needs. Current Product Configuration functionality does not meet the requirements of a Manufacturing Execution enterprise.	Other manufacturing policies, such as Product Postponement, influence the timing of final assembly and change how products are planned, produced and shipped. The planning and execution tools need to address alternate configuration and assembly options.
Sales Order coupling/integration with Daily Production Schedule	In a Manufacturing Execution environment, items are only produced in response to specific demand, which includes Customer Orders and Finished Goods replenishment orders.	The link between the demand and production needs to be maintained right through to Finished Goods inventory.

Table 6 (continued)

Anticipated ERP changes

Backflushing in real-time	Backflush performance is an issue in a fast moving environment. The requirement to backflush all operations at the end of the line can create a record locking situation which degrades system response times.	The Demand Flow model calls for the use of flat Bills of Materials; all subassemblies and phantoms are eliminated. Adoption of shallow BOMs would enable backflushing to be processed more rapidly. Alternative backflushing procedures are necessary to optimizing performance.
Demand Smoothing	A visual interface to a Detailed Execution Schedule makes demand smoothing viable in a fast moving environment. Ideally, forecast and demand over a number of time buckets can be seen and updated on a single screen. This interface should enable evaluation of alternate schedules to calculate the effect on resource and material requirements.	The production planning for a Manufacturing Execution environment requires daily, weekly, and monthly planning, instead of the 6-12 month planning most factories use. The ERP/FM software needs to allow for smaller increments of time for scheduling and planning.

3. 2.8. CONCLUSION

Models and theories around MES as well as the MES market, vendors and integrators will evolve. The way by which manufacturing (and services) is planned and controlled will also change.

McClellan (1997:ix) states that MES are specific only in concept.
The CONCEPT of MES is well established and is integrated inextricably within planning and control systems. Further discussion on the integration of enterprises through information technology is done in the remainder of this chapter.

3. 3. THE EVOLUTION OF INFORMATION TECHNOLOGY

3. 3.1. COMPUTER INTEGRATED MANUFACTURING (CIM)

"A CIM system is commonly thought of as an integrated system that encompasses all the activities in the production system from the planning and design of a product through the manufacturing systems, including control. CIM is an attempt to combine existing computer technologies in order to manage and control the entire business."
(Degarmo,1997:1190)

According to Cuttica (1998,www.icsmagazine.com/soft0598.htm) intense competition and time to market imperatives are driving the need to integrate all of the computing systems in a manufacturing enterprise into a comprehensive information technology (IT) structure. Value are added to a business, if the IT architecture and data exchange are understood. The same can be applied to MES. "It is the IT architectures that help MES to enable true enterprise-wide, plug-and-play interoperability among multiple applications."

Before the creation of the term MES, Theodore J. Williams of Purdue University (Handbook,1991:674) described CIM as future trend: *"Plant-wide computer control, computer integrated manufacturing (CIM) and hierarchical computer control systems are all terms describing the expected future trend in all large scale manufacturing (overall optimization, scheduling, coordination and dynamic control of the entire plant by means of a multi -element, distributed yet totally integrated computer system."*

The term MES was created to describe the suite of software that integrates planning and control systems, to establish exactly what Williams described. The conclusion can be made from this that both MES and CIM are attempts to accomplish enterprise integration through information technology. Some investigation is needed to determine whether MES is only an element of CIM or whether it is a concept with its own right of existence.
"Although CIM and MES are very similar concepts, there was significant development during the past few years" (McClellan,1997:ix).

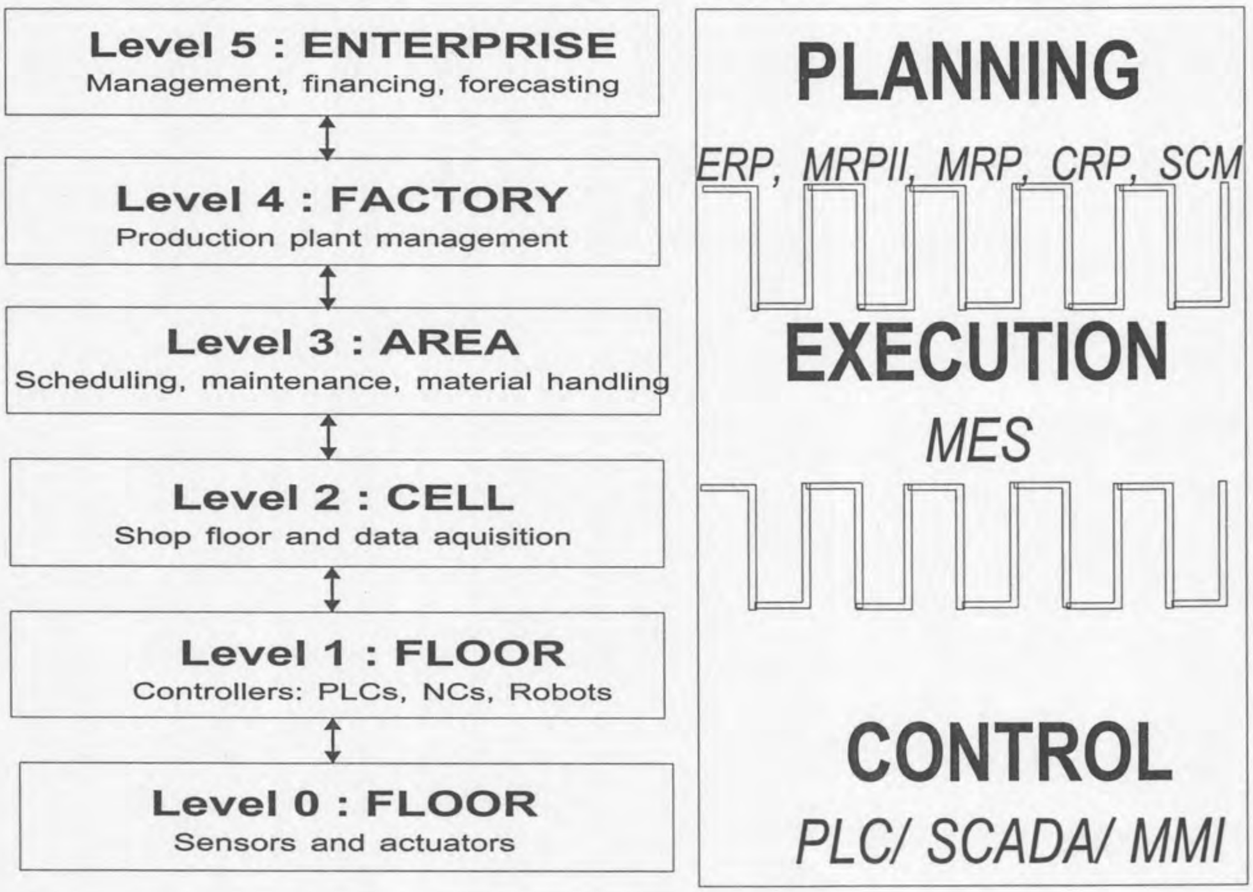
The differences between MES and CIM are related to business models as well as underlying technology. The most significant differences between the business models of MES and CIM are the following:

- The scope of CIM include the entire model, while MES is only represented by the middle layer.
- The CIM-model is more complex and consists of double the amount of layers as indicated in *Figure 14*. Systems based on this model is, thus, much less flexible and reactive.

3. 3.2. BUSINESS MODELS OF MES AND CIM

Figure 1

CIM compared to MES, through business models



3. 3.3. UNDERLYING TECHNOLOGY

MES has taken on broader and, in some cases, totally different meaning, providing the infrastructure that CIM never had. Instead of custom designing software programs on a contract-by-contract basis, MES are based much more on standard reusable application software. The results include lower costs and shorter implementation time (McClellan,1997:ix). Based on the technology of the day MES was modeled in 1993 by AMR Research as a group of functions around a relational database with wired communication connections to Materials Requirements Planning (MRP) and controls.

Swanton (1998:www.amrresearch.com/repac) declared, however, that the way by which MES are using information technology has changed rapidly over the past few years: "*Integration through a common data model on a relational database proved impossible in the plant systems market. No vendor had all the parts, and no one could agree on a common model. The lack of a common data model meant sky-high integration costs.*"

This information technology, doomed by Swanton, is also the basis for CIM: *"Computer-integrated manufacturing systems as basically a network of computer systems tied together by a single integrated database".* This may one of the reasons for the low success rate of CIM – as explained by Degramo(1997:1190): *"CIM is an approach that very few companies have adopted at this time, since surveys show that only 1%-2% of U.S. manufacturing companies have approached a full-scale use of FMS and CAD/CAM let alone CIM systems."*

According to McClellan (1997:ix) several application disappointment is to blame for the fact that CIM has fallen in total disuse. A detail study of underlying information technology does not fall within the scope of this dissertation, nor has the author the authority to comment on this. It is, however, clear from the study of CIM that information technology and management needs to be considered.

" The removal of production bottlenecks increases the effectiveness and efficiency of manufacturing processes. Through native drivers or ODBC and OPC interfaces, MES can directly connect the computing environments, allowing real-time decisions to influence the running of the business. And through Internet/intranet tools, production managers can view production trends or other plant information from anywhere in the world. Finally, some MES tie into existing email systems, and can use this technology to generate alarms and provide production updates to selected personnel.

(Guttica,1998:www.icsmagazine.com/soft0598.htm)

3. 3.4. THE INTERNET

According to CIMx (1998:www.cimx.com) the explosive growth of Internet is encouraging the use of Internet technology to build Intranets in large companies. The growing need for major improvements in manufacturing productivity creates an opportunity to achieve breakthroughs in the use of these new information technologies for next generation products and services. Technology now enables large scale implementation of inexpensive distributed networks of personal computers and network computers for manufacturing firms where only expensive workstations were previously used. Installations can take place over time to suit the customer. Each cluster can be fully justified economically and functionally before proceeding with the next phase of the plan. This increases productivity, decreases the time for positive return on investment, and greatly reduces the risk associated with a large project.
Growing interest among manufacturers in Web browsers, Internet-enabled applications, viewing tools, and home pages is fueled by the need for inexpensive, scaleable, enterprise-wide integration.

Wingate (1996:40) states that the Internet has rewritten the rules on connectivity. Intranets, in a sense, are small, private Internets within individual companies. Intranets can span the globe, but the emphasis is on providing access and data sharing within a homogeneous unit. Both the Internet and Intranets exploit the power of browser technology, which effectively changes the world of distributed computing that the classic client/server compution architecture created. User desktop access remains, in essence, a client connected across the Internet/ Intranet bridge but the desktop browser fetched both the program and the information each time it stars a new computing work task. This enables software upgrading in one place at one time and ensures consistent data accuracy with little overhead.

Although it is believed that many companies remain hesitant about committing to the Internet due to security concerns and other issues, Fulcher (1996:40-46) predicts that more will be implementing standard Web browsers and server software on their own intranets. The most common of these in-house applications include "Web visualization" tools, which provide various real-time diagnostic capabilities from remote locations using Internet browsers. Managers, supervisors, and other technicians gain access to mission-critical data, and in some cases, full monitoring and control capabilities.

Clouther (1999:www.arcweb.com/arcsite/Search/search.asp) predicts that the Internet will increasingly be used for inter-company communication:
Internet browsers and Java applications provide the mechanism whereby a business application can intelligently access and retrieve data across the Internet/ intranet/ extranet. This is prevalent in the growing number of businesses moving into electronic commerce involving business-to-business and customer-to-business scenarios. The browser works across the horizontal business layer from suppliers to customers. For example, purchasing uses the Internet to search for suppliers of specific products, prices, availability, specifications and delivery dates. With contracted suppliers, or partners, the Internet allows them to access the inventory levels of every plant or location that stocks their products worldwide, and initiate a restocking order to be delivered from the nearest facility before the item is stocked out.

These technologies provide a clean connectivity not previously available, but no intelligence is related to the actual transferring of information. Therefore, they cannot truly be defined as integration. These technologies will, however, definitely enhance the intergration of Manufacturing Execution Systems.

3. 3.5. OBJECT ORIENTATED PROGRAMMING AND CLIENT/SERVER TECHNOLOGY

"MES are essentially an integrating set of functions - providing links between planning and control, design, product execution, sales force and delivery mechanisms, and customers and supply capabilities. For this reason Application Programmer Interfaces (API) and data transport or communications mechanisms are in some ways a center piece of MES functionality and not just an incidental technical detail."(Theron,1998)

Wibberley (1998:www.adroit.co.za/press/art04.html) explains that a dominant effort in software development over the past few years has been the use of object oriented technology. This methodology has become widely accepted as the as the most effective way of designing and implementing software that is robust and flexible enough to meet future and as yet unforeseen requirements. Both the SCADA, MES, ERP layers are now working off the following common threads: a common operating system, applications designed with objects in mind and all developers have common binary interfacing standards to work from. Thus the ability to expose and interface relevant inter-application objects' properties along a distributed technology backbone is now and will become ever more possible.

By utilizing SQL and ODBC database connectivity standards, these point solutions can be integrated with existing MES systems and ERP systems to add needed functionality. (Marks,1997:www.industry.net/nmw97/MES1d.htm)
What the data processing establishment could never achieve on mainframes and midrange systems was now possible through client/server technology. "Plug and play" concepts, as well as open systems architecture, allowed companies to build distributed applications that provided true Enterprise Resource Planning (ERP) and Computer Orientated Manufacturing Management Systems (COMMS) capabilities. The low cost of communications technology, combined with easily configurable local area networks (LANs) and wide area networks (WANs), enabled flexible, scaleable, distributed systems, as well as Computer Integrated Manufacturing (CIM) to become a reality. Most recently on the manufacturing scene is MES which allows planning execution, and control activities to be linked together. (Martin,1995:34)

3. 3.6. CONCLUSION

Developing an understanding of data exchange with respect to an enterprise's IT architecture, then using that understanding to enable the exchange, is the key to unlocking huge unrealized business value. It is the IT architectures that help MES to enable true enterprise-wide, plug-and-play interoperability among multiple applications. (Guttica,1998:www.icsmagazine.com/soft0598.htm)

Information Technology evolves even faster than the MES concept and has a direct influence on the way MES are established.