

UNIVERSITY OF KWAZULU-NATAL

**Successfully Implementing a Manufacturing Execution  
Systems (MES) Solution**

By

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**DECLARATION**

This research has not been previously accepted for any degree and is not being currently submitted for any other degree at any other university.

I declare that this Dissertation contains my own work except where specifically acknowledged

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Signed..... 

Date..... *10 August 2007.*

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The undersigned certify that they have read and recommend this dissertation to the University of KwaZulu-Natal

Title of Dissertation: **Successfully Implementing a Manufacturing Execution Systems (MES) Solution.**

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Date.....

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### **Abstract:**

A **Manufacturing Execution System (MES)** is a system that companies use to measure and control critical production activities. As the installed base of MES installations grows, claims that MES does not have a positive impact on the day-to-day operations within manufacturing companies are more common. Documented results and anecdotal evidence are also now available. Due to the pace at which this market has grown, more and more vendors and implementation partners are entering the market.

Organizations that wish to successfully implement a MES solution need to be well informed and educated about the intricacies of software implementations. Organizations need to ensure that they are in control of the implementation and not at the mercy of the software vendors and implementation partners for success. Organizations need to plan the whole implementation process thoroughly and top level management need to drive the initiatives within the organization to ensure success.

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## **Chapter 1**

### **Introduction to Dissertation**

#### **1.1 Introduction**

Computer software systems have become an integral part of most manufacturing and mining organisations. One of the latest software systems to emerge is the Manufacturing Execution System (MES) solution, a technology that provides on-line application software that organisations rely on to manage every aspect of their manufacturing processes. Seen as a bridge from the plant floor to the rest of the enterprise, MES solutions are fast becoming the software solution that all manufacturing enterprises desire (Trebilcock, 2006). The MES market is forecast to grow at a rate of 15% per year for the next five years. The current size of the MES market is now estimated at \$ 2 billion worldwide from \$ 1.06 billion in 2004. (Trebilcock, 2006)

The term Manufacturing Execution System was coined by Advanced Manufacturing Research (AMR) in 1990 to describe the role of computers in the area of manufacturing. MES is the generic name for software that manages and tracks all activities and resources throughout the entire production process, including machines, material, and people and provides the company with detailed history on all these processes (Purtell, 1993).

This dissertation, *Successfully Implementing a Manufacturing Execution Systems Solution*, aims to provide strategic guidelines to organisations that plan to implement an MES solution. These guidelines will assist organisations in planning and scoping their whole project from inception to eliminate as many of the implementation surprises and stumbling blocks as possible. These guidelines will empower decision makers in organisations to manage not only the implementation but also the many intricate “soft issues” that can determine the success or failure of the project. This study covers the whole MES implementation process from the e-readiness study at the start of the project to selecting a vendor, the pilot/full implementation and finally the project signoff.

## **1.2 Problem Statement**

Manufacturing Execution Systems solutions have evolved to fill the communication gap between the manufacturing planning systems (MRP, MRPII, ERP, etc.) and the control systems used to run equipment on the plant floor (SCADA & PLC.). Typical MES modules include Downtime, Production, Quality, Tracking, Cost, Planning, Maintenance, and Recipe.

MES has many different forms and formats, the MES system found in a pharmaceutical plant will differ from the MES system found in a platinum plant. Both plants deal with small quantities with high value but the pharmaceutical plant will be focussed mainly on tracking and tracing the origins of all the ingredients that goes into their product (Sparrow, 2005) where in the platinum plant they will focus mainly on improved production through OEE - Overall Equipment Effectiveness (Weidemann, 2006). Although MESs are in widespread use throughout most industries, the systems are rarely described similarly, nor are the functions identical. An MES in use at an electronics manufacturing facility is similar only in concept to one used in the food processing industry, and they will both differ substantially from the requirements of one used by a pharmaceutical manufacturer. They vary greatly within industries, within organisations, and even between plants within a company (McClellan, 2004).

Since Advanced Manufacturing Research (AMR) coined the term MES, there have been many attempts at implementing MES solutions. Unfortunately, many of these attempts have failed. The failures have been caused by many different reasons (Bruhn, 1997). Some failed because the scope was too broad, an attempt was made to cover too many aspects of the manufacturing environment. Thus an integration nightmare was created. In these cases it was not unusual to see the project abandoned after years of effort and many millions of dollars wasted (Bruhn, 1997).

Other efforts failed because a particular MES package was forced to fit a manufacturing environment for which it was not optimally suited. An example may be where an MES package geared for discrete manufacturing was forcibly implemented into a process industry. In many of these cases the application was simply never used, or at best, limped along providing marginal benefit (Bruhn, 1997). The Manufacturing Execution Systems Association

(MESA) reports great benefits from organisations that have successfully installed MES solutions. Unfortunately many organisations fail to complete their MES implementations or do not get the expected benefits from the implemented solution.

According to McClellan (1997) some MES projects fail, not because of computer or software malfunction but most frequently, from poor definition. Extensive customisation of the software can lead to faults in the system and serious integration problems with the other systems.

MESA case studies on the benefits of implementing a MES solution do not contain sufficient statistics on failed MES implementations where organisations did not receive the benefits that they were led to believe they could achieve from a MES solution. MES vendors do not like their failed projects to become public and therefore, shifting the blame for the failed implementation onto the organisation protects their credibility.

Many very knowledgeable MES writers like Michael McClellan, Greg Gorbach from AMR and the journalists at MESA comment about the many failing MES projects. Projects are failing and organisations are losing money because of this.

Preliminary researches on the topic of software implementation lead to a suspicion that organisations were not well-informed about the intricacies of software implementations. If this suspicion was correct it would mean that organisations were at the mercy of the software vendor for success and needed to be educated in the implementation of MES solutions to ensure that they were in control of the implementation and would ensure the success of the project.

### **1.3 Scope of study**

The field of study for this dissertation falls under the discipline of Strategic Management. Strategic Management is defined as the set of decisions and actions that result in the formulation and implementation of plans designed to achieve a company's objectives.



These are the formulation of the company's mission and planned goals with the implementation of the MES solution. The analysis of the current internal conditions and capabilities. An assessment of the company's external factors. Identifying the most desirable options by evaluating each option in the light of the company's mission and goals. The selection of long and medium term objectives and grand strategies that will achieve the most desirable options. Development of annual objectives and short-term strategies that are compatible with the selected set of long and medium term objectives and grand strategies. The implementation of strategic choices by means of budgeted resource allocation in which the matching of tasks, people, structures, technology and reward systems is emphasized. Finally the evaluation of the success of the strategic process as an input for future decision making (Pearce & Robinson, 2003).

#### **1.4 Breakdown of sources, methods and procedures of the research**

Most of the data used is primary data, collected directly from the respondents personally, by means of an email with a questionnaire attached. Secondary data was collected through books, articles, white papers and journals outlined in the literature review. Most of the documentary data was collected via the various search engines on the World Wide Web.

The research questionnaire was designed to answer the research questions that are outlined at the end of Chapter 2. This questionnaire was sent to 560 selected individuals in 508 organisations, at various levels in 57 countries. All of the individuals are involved in plant automation in their organisations in some way or another (see appendix).

#### **1.5 Conclusion**

The purpose of this chapter was to introduce the research topic to the reader. This chapter explained the topic and the reasons why the topic was deemed necessary to research further. This chapter briefly touched on the problem statement and discussed the scope of this specific study field. Finally the chapter briefly looked at the breakdown of data sources, methods and procedures.

Chapter 2 discusses the literature review and looks at the various literature on the specific sub topics. Chapter 2 is divided into sub headings each pertaining to a specific aspect of the MES implementation process. At the end of Chapter 2 the research questions are formulated on the basis of the input from the literature reviewed.

## **Chapter 2**

### **Background to Manufacturing Execution Systems (MES)**

#### **2.1 Introduction.**

MESA reports great benefits from companies that have successfully installed MES solutions. Unfortunately many companies fail to complete their MES implementations or do not get the expected benefits from the implemented solution. This dissertation aims to provide a guide to successful MES implementation for companies and vendors who are considering implementing an MES Solution.

The following search engines were used: google.com, google scholar, google suggest, yahoo.com, search.com, isleuth.com, dogpile.com, metacrawler.com. The following keywords were used: MES, MES solutions, Implementing MES, Manufacturing Execution Systems, Manufacturing Execution Systems Solutions, Implementing Manufacturing Execution Systems, Manufacturing systems, Collaborative manufacturing, implementing software.

Chapter 2 starts by defining the MES solution. After the definition this chapter goes into discussions on the major issues companies experience during a MES implementation. Finally the future of MES solutions is discussed, and the research questions conclude this chapter.

#### **2.2 Definitions of MES solutions.**

The term Manufacturing Execution System was coined by Advanced Manufacturing Research in 1990 to describe the role of computers in the area of manufacturing. MES is the generic name for software that manages and tracks all activities and resources throughout the entire production process, including machines, material, and people and provides the company with detailed history on all these processes (Purtell, 1993).

Seeley (1997) feels the term manufacturing execution system describes a suite of software functions that reside between enterprise resource planning systems and manufacturing control systems. An MES solution makes it possible to pass information back and forth between an ERP system and programmable logic controllers, distributed control systems, and supervisory control and data acquisition systems. An MES solution therefore ties together many systems and functions, including maintenance, laboratory, document control, training, standard operating procedures, raw-material handling, and corporate information systems. From the MRP/ERP system, the MES receives information on orders, bills of materials, drawings, resource requirements, process plans, work instructions, assembly steps, manufacturing process plans, raw materials, and inventory; it then translates this information into a manufacturing execution plan that reflects current conditions on the plant floor.

Fraser (1997) from the Manufacturing Execution System Association International (MESA International) gives an official definition for MES. MES delivers information that enables the optimisation of production activities from order launch to finished goods. Using current and accurate data, MES guides, initiates, responds to, and reports on plant activities as they occur. The resulting rapid response to changing conditions, coupled with a focus on reducing non value-added activities, drives effective plant operations and processes. MES improves the return on operational assets as well as on-time delivery, inventory turns, gross margin, and cash flow performance. MES provides mission critical information about production activities across the enterprise and supply chain via bi-directional communications (Fraser, 1997).

Vinhais (1998) defines MES as a solution that provides all the necessary and correct information to operators or assemblers at the correct time. Quality, manufacturing and engineering data, stored in separate databases, is accessible across the network for combined reporting. An MES also allows operators to request resources from other department databases linked within the system. In short, an MES gives a quality department the means to support its internal and external customers more easily, quickly and with much more data for example by providing a database of detailed, timely and accurate operational information it can help standardise quality processes across various plants resulting in utilisation advantages such as reducing the number of job skill-set needed at each plant.

Gartner's IT Glossary on the worldwide web defines MES as a computerised system that formalises production methods and procedures within the manufacturing environment, providing online tools to execute work orders. The term is generally used to encompass any manufacturing system not already classified in the enterprise resource planning (ERP) or open control systems (OCS) a manufacturing system that is based on a set of commercially available, standards-based technologies, and that permits the open exchange of process data with plant systems and business systems throughout a manufacturing enterprise, whereas "Control" refers to process control for discrete, batch and continuous-process manufacturing, as well as Computer Numerical Control (CNC) and other motion control categories.

In the broadest definition, MESs include computerised maintenance management systems (CMMS), laboratory information management systems (LIMS), shop floor controls (SFC – a system of computers and controllers used to schedule, dispatch and track the progress of work orders through manufacturing based on defined routings), statistical process control (SPC) systems, quality control (QC) systems, and specialised applications such as batch reporting and control.

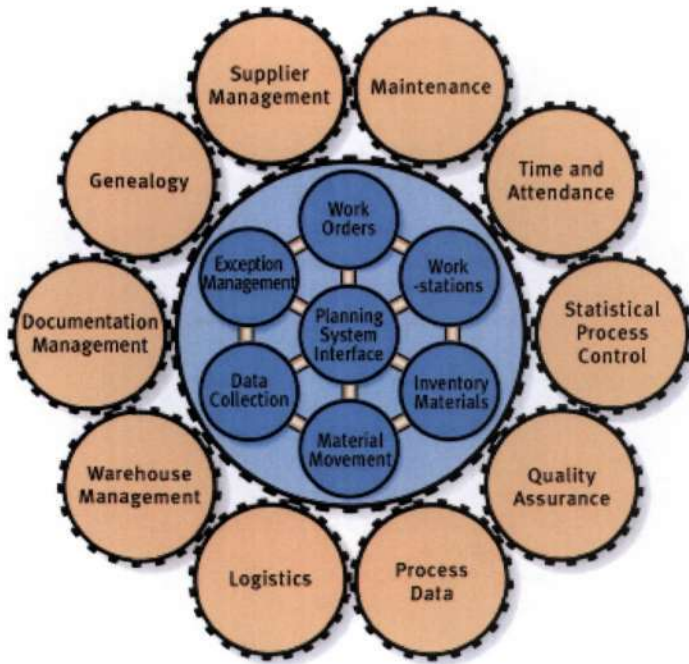
### **2.3 Functionality of MES solutions.**

MES has many different forms and formats. Although MESs are in widespread use throughout most industries, the systems are rarely described similarly, nor are the functions identical. Despite such disparities, some similarities exist regarding general form and function. System components can be divided into two categories: core functions, which are directly associated with managing the production process and are included in most vendor packages; and support functions, which are somewhat peripheral to the central order management process. Figure 2.1 illustrates the MES functions, using the notion of a system of gears (McClellan, 2004).

#### **2.3.1 Core Functions**

To provide a better understanding of MES and the integral role it plays in executing business objectives, the core functions of MES are explained. The MES system's core function includes a planning system interface. This function describes the connection with

the planning system (ERP) and defines how and what information is exchanged (McClellan, 2004).



**Figure 2.1 MES Functionality.** (McClellan, 2004)

(McClellan, M. 2004. Execution Systems: The Heart of Intelligent Manufacturing. *Intelligent Enterprise Online*)

The order management function includes the accumulation and management of work orders that have been received from the ERP system. This function performs the following common tasks: making changes (such as quantity) to orders; combining or splitting orders; running short-term what-if analyses to determine best current resource use; and prioritizing and scheduling (McClellan, 2004).

The workstation management function is responsible for implementing the works order production plan, workstation scheduling, and the logical configuration of each workstation. The current resource availability along with the current schedule requirements by operation are normally maintained (McClellan, 2004).

An inventory tracking and management function develops, stores, and maintains the details of each batch, lot, or unit of inventory of the work-in-process (McClellan, 2004).

The material movement management functionality is either manual or automated. Organizations schedule and manage the movement of material through this function. The data collection segment acts as the collection point, clearinghouse, and translator for data that is needed and/or generated on the plant floor (McClellan, 2004).

The exception management function provides the ability to respond to unanticipated events that affect the production plan, such as a bill-of-materials item shortage for a work order in process. Most MESs include the ability to react to exceptions following rules that are typically plant centric. Exception management generally requires some level of configuration or customization in order to meet local requirements (McClellan, 2004).

### **2.3.2 Support Functions**

The following list of MES support functions is only a representation of possibilities and is not an exhaustive list of what is available or in use.

- Maintenance management function or "asset" management.
- Time and attendance systems.
- Statistical process control (SPC) systems.
- Quality formulation and implementation systems.
- Process data/Performance analysis systems.
- Document/product data management systems.
- Genealogy/Product systems.
- Supply chain management systems.
- Warehouse management systems.
- Product location information and order fulfillment instruction systems. (McClellan, 2004).

## **2.4 Key drivers for implementing a MES solution. (Advantages of MES)**

Prior to the advent of the MES solution, information technology tools were incapable of providing the real-time data that production managers required to make accurate, informed decisions because previous systems were of a very low technology standard, information supplied was not timely or accurate, systems were not flexible enough for shop-floor changes and integration between the multi vendor applications was difficult (Pieterse, 2005). Today, MES solutions can supply this information to these systems and enable them for example, to perform the mapping of customer orders to specific production runs. This mapping enables the production manager to inform the customer when the order will be expedited and when the order will be completed (Kall, 1999).

By being able to control and dispatch orders in a timely and organized fashion, the production manager will have more time available for his primary role which is production planning. By having real-time information available the MES system can frequently update the production scheduler with information regarding the state of the labor force, material quantities and machine downtime (Kall, 1999).

The MES solution can define and enforce production procedures and business rules as set by the production or plant manager. The system will automatically alert production personnel to deviations from the set production rules enabling them to take immediate corrective action and reduce a potential loss to the absolute minimum. The MES solution provides information about dispatching and coordination of material and the required information for unit operations (Kall, 1999). Real-time production reporting on material usage, scrap, rate of production, status of production lines can be automated and these reports can be produced at any specified time on a day or a week or even at the end of the month. The reports can also be automatically emailed to any location required (Kall, 1999).

The MES system will integrate to the SPC/SQC (quality management) system to provide real-time information on the quality of the production process and the products being produced. This information about the processes could include temperature, speed and settings of the machinery. Information regarding the products being produced includes the percentage

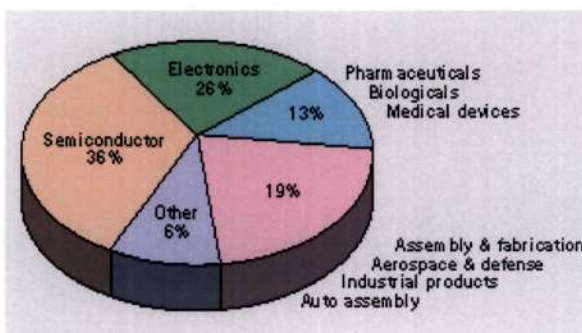


deviation from the specifications. The system will provide real-time feedback and automatic alerts to positively affect the current production run and keep it producing within the set parameters that have been set for that specific production run. By defining and enforcing specific equipment, routes, operator and material combinations for a particular work order or product, the MES system automatically ensures compliance (Kall, 1999).

Further reasons for installing an MES solution are that it provides a tool for efficient data gathering, and simpler, more accurate management of documentation, all of which can lead to lower manufacturing and regulatory compliance costs. Below is a pie-chart of the 1996 manufacturing execution system market by industry (Advanced Manufacturing Research).

A survey of users across all industries, conducted by the Pittsburgh-based Manufacturing Execution Systems Association International (MESA), found that an MES solution reduces manufacturing cycle time, work-in-progress, manufacturing lead times, and product defects. Data-entry time is also reduced. Consilium Inc. (Mountain View, CA), calculates that its MES package is responsible for reducing document cycle times by 60% at one pharmaceutical plant and saves 64% of costs associated with documentation for GMP purposes (Seeley, 1997).

**Figure 2.2 MES solutions by industry vertical.**



(Seeley, 1997)

Pacesetter, Inc. (Scottsdale, AZ), in manufacturing the electronic circuitry for its cardiac rhythm management products, installed an MES to automate recordkeeping. Previously, at each assembly step, an operator manually entered process information and initialed the paper to verify that each step was completed. This control procedure was time-consuming,

cumbersome, and difficult to manage. The MES eliminated the paperwork while speeding data collection and improving data integrity; it reduced cycle times by one week, reducing work-in-progress inventory costs by \$500,000 annually. Reduction in scrap saved another \$25,000 annually. Labor costs fell by \$200,000 yearly (Seeley, 1997).

In improving productivity and quality, an MES identifies manufacturing problems and communicates the information to the necessary personnel in real time. Problems can be speedily resolved to minimize work disruptions. The QC department is instantly notified of a variance and can correct it without delay. Production is notified instantly when it can proceed. Information is shared in real time among interested parties to help resolve a defective product or process, again speeding production flow and throughput. Administrative load lightens, and the opportunity for documentation and GMP compliance errors is substantially reduced (Seeley, 1997).

There are major business issues driving the expanding use of MES solutions, including demand driven manufacturing, real-time enterprise objectives, and intelligent enterprise applications. Less adversarial and more inclusive managerial approaches, such as collaborative planning, forecasting and replenishment (CPFR) and collaborative manufacturing product life-cycle management (PLM) have greatly expanded the user audience that depend on MES information support to do their jobs (McClellan, 2004).

MES has provided its users with some of the most impressive benefits of any manufacturing software. MESA International's White Paper No. 1, 1996 outlines many of these issues based on actual MES user experiences. This research shows that the benefits users experience are significant.

- Reduced manufacturing cycle time by an average of 45%.
- Reduced data entry time, by 75%.
- Reduced work in progress (WIP) by an average of 24%.
- Reduced paperwork between shifts by an average of 61%.
- Reduced lead time, by an average of 27%.
- Reduced paperwork and blueprint losses by an average of 56%.

- Reduced amount of rework due to these losses by 56%.
- Reduced product defects by an average of 18%.
- Reduce waste.

The benefits listed above are validated by MESA International. (MESA White PAPER No 1, 1996).

The global information provided by MES translates into significant benefits for manufacturers like enhanced decision-making capability (Phadke, 2006). Available-to-promise (ATP) is a concept that denotes the quality available for a new customer order. Accepting the order for a particular quality on a due date depends on this ATP quality determined in the MRP schedule. The responsibility for accepting this order lies with the scheduler in the manufacturing planning department. With the visibility provided by MES to the business leader, the business leader can take decisions based on ATP criteria. Based on the real time information that is available from MES, the business leader can assess the profit potential of that order and decide whether to accept the order using ATP criteria. Thus, the decision-making is elevated from the manufacturing layer and taken closer to the business layer. Business leaders are in a better position to take decisions involving product mix, pricing and contracts (Phadke, 2006).

In addition the system provides the ability to identify and weed out defect root causes. MES systems identify the root cause for product quality related problems, these are difficult to identify manually (Phadke, 2006). Global visibility of parameters such as operational equipment effectiveness (OEE) and asset management helps manufacturers identify key performance indicators (KPI) and set service level agreements. For example, if an average yield goes below a defined percentage, then alerts can be directed to the right people enabling them to take corrective action before a production line stops. Similarly, machine maintenance schedules can be coordinated to match production schedules and prevent breakdowns. In the absence of a capability such as genealogy tracking of the component parts at the global level, the liability risk for automobile manufacturers could be enormous in warranty claims or product recalls. With upcoming industry initiatives like waste electrical and electronic

equipment (WEEE) and restrictions on the use of certain hazardous substances (RoHS), the track and trace capabilities of MES have never been so important (Phadke, 2006).

In industries like the pharmaceutical industry there is a need for regulatory compliance. MES's ability to satisfy record keeping requirements with no additional expense is extremely advantageous to manufacturing organisations. The data collection feature, which provides important inputs to the quality management system, helps manufacturing organisations satisfy regulatory demands. Additionally, CAPA (corrective and preventative action) systems can be integrated with MES systems to ensure compliance (Phadke, 2006).

Most manufacturers justify their MES investment on tactical and easily measurable operational metrics: labour, inventory measures, lead times, maintenance, data accuracy and reporting (Phadke, 2006). However it may be worthwhile to go beyond evaluating the gains through local operational improvements. Major gains can be achieved by leveraging the global visibility provided over the broader supply chain. MES provides a manufacturer the tools to identify opportunities across different sites and other business processes (Phadke, 2006).

Good MES systems drive manufacturing processes, capture every operating detail and help people understand what it means. A good MES system enables fast, appropriate reaction to changing situations. The system has to be active, with immediate detection and notification of any non-conformance to enable detailed production rules to be enforced. When problems occur, root-cause analysis requires complete unit history records (Gorbach, 2005).

When an MES is up and running, medical device manufacturers will notice many welcome changes on the plant floor and beyond. Of course, one of these changes is a dramatic reduction in shop-floor paperwork and in the number of filing cabinets. Another is the reduction of labour-intensive device history record (DHR) reviews. In some cases, end-of-process DHR reviews can be completely eliminated. QA inspectors are now free to help the company improve processes and quality.

One of the most important features of an MES is its ability to detect and react to production problems early in the process. If a product or process value is outside of specification limits, for example, an MES detects it and automatically suggests one or more prescribed actions. These actions could include directing the product to a rework station, sending a message to engineering, and generating a non-conformance report that describes the problem and the specific steps taken to correct it (Knight & Lamb, 2006)

An MES database provides valuable process data not normally or easily extracted from paper-based systems. For example, an MES can help plant personnel uncover rework loops that reduce manufacturing efficiency and increase the risk of product failure. Tracking rework in paper-based systems requires looking through paper device history records (DHRs) to piece together what happened. Some paper recordkeeping systems do not even require operators to report that rework was done on a product, only that the product was good when it left their station (Knight & Lamb, 2006).

MES makes it easier to track rework, MES can be set up to require the recording of all rework done by an operator. Such recording helps manufacturers zero in on the processes that require the most rework and therefore need improvement (Knight & Lamb, 2006). An MES also makes it easy to trace components and assess their condition and performance. This is difficult when data collection is done using a paper-based system. A manufacturer seeking information about a component in a particular type of device would have to retrieve the paper DHRs, as well as any repair data on file at service centres that might be scattered across the country or even worldwide (Knight & Lamb, 2006).

By contrast, a manufacturer can quickly retrieve all of the DHR and repair data for a device simply by querying an MES-based data-collection system. These data can be used to quickly trace failures back to components made by particular vendors. For example, a query to the system might show that nine of the last 10 valves that failed in the field were made by vendor A. This would tell the manufacturer to focus on vendor A rather than take the matter up with all of its valve suppliers (Knight & Lamb, 2006).

The query might also retrieve additional information, such as what went wrong with the valves and whether they were all from the same lot. This information can be supplied to vendor A to help the supplier solve its quality problem (Knight & Lamb, 2006). With this type of component data, manufacturers can create scorecards that help them monitor and compare the performance of different suppliers. These scorecards can provide useful information such as the mean time to failure (MTTF) for each supplier's products, whether and how much each product's MTTF is increasing over time, and which supplier's products have improved the most in a certain time period (Knight & Lamb, 2006).

When manufacturing companies establish flexible, responsive information infrastructures that rapidly respond to changes in product, process, people and procedures, such as those provided by MES, they attain the necessary agility required to compete in today's business climate. The final result is product superiority; increased yields, reduced cycle times and production costs, and accelerated responsiveness to customer needs and market demands also known as competitive advantage (Kall, 1999).

## **2.5 Organisational Issues.**

Ross and Weill (2002) offer a list of six IT decisions for which senior management should be responsible, and not IT executives, to avoid IT disaster and more important, generate real value from their IT investment.

1. How much money does the company want to spend on MES? Given the uncertain returns on IT spending many executives are concerned whether they are spending too much or perhaps too little on IT. Most companies' senior managers evaluate the industry benchmarks as a way of determining appropriate spending levels. In successful companies studied, senior managers approached the question of IT spend very differently. First they determine the strategic role that IT will play in the organisation and only then do they establish a companywide funding level that will enable technology to fulfil that objective (Ross & Weill, 2002). IT spending can be designed to meet immediate needs and allow for an array of future benefits only if IT and business goals are clearly defined. Companies that have undefined or unclear goals

like, “providing information to the right people at the right time” cause the internal department to create counter measures against the vagueness for example the over budgeting of projects to help fund smaller projects(Ross & Weill, 2002).

2. Which business process to allocate the funding to? If IT initiative are not coordinate centrally in an organisation, executive will soon find that the have many projects in their company that are often conflicting one and other. In some companies surveyed it is not uncommon to find companies of a few hundred people that have a few hundred IT projects under way. Clearly, not all of them are equally important. It was found that senior managers in these companies are often reluctant to step in and choose between the projects that will have a significant impact on the companies’ success and those that provide some benefits but are not essential (Ross & Weill, 2002). Leaving the decision of which projects to support to the IT department will result in the IT department focussing on the projects of influential managers and ignoring the projects of less influential managers or departments. Presented with a list of approved and funded projects, most IT units will do their best to carry them out. This typically leads to a backlog of delayed initiatives and an overwhelmed and demoralised IT department (Ross & Weill, 2002).
  
3. Which IT capabilities need to be companywide? Executives have recognised the significant cost savings and strategic benefits that come from centralising IT capabilities and standardising IT infrastructure across an organisation. This approach leverages technology expertise across the company, permits large and cost-effective contracts with software suppliers, and facilities global business processes. At the same time, though, standards can restrict the flexibility of individual business units, limit the company’s responsiveness to differentiated customer segments and generate strong resistance from business unit managers (Ross & Weill, 2002). When IT executives are left to make decisions about what will and will not be centralised, they typically take one of two approaches. Depending on the company’s culture, either they insist on standardising everything to keep costs low or recognising the importance of business unit autonomy, they grant exceptions to corporate standards to any business unit

manager who raises a stink. The former approach restricts the flexibility of business units; the latter is expensive and limits business synergies. In some instances, systems using different standards can work against each other, resulting in a corporate IT infrastructure whose total value may be less than the sum of its parts. Consequently, senior managers should play the lead role in weighing these crucial trade-offs (Ross & Weill, 2002).

4. How good do the IT services need to be? An IT system that does not work is useless. But that does not mean every system must be wrapped in gold-plated functionality. Characteristics such as reliability, responsiveness, and data accessibility come at a cost. It is up to senior managers to decide how much they are willing to spend for various features and services. For some companies, top-of-the-line service is not negotiable. Investment banks do not debate how much data they can afford to lose if a trading system crashes; 100% recovery is a requirement. But fortunately every company is not Merrill Lynch and most companies can tolerate limited downtime or occasionally slow response times. The companies must weigh the cost of the inconvenience against the cost of preventing the problems (Ross & Weill, 2002). Decisions concerning the appropriate levels of IT service need to be made by senior business managers. Left to their own devices, IT units are likely to opt for the highest levels because the IT unit will be judged on such things as how often the system goes down. IT people should provide a menu of services options and prices to help managers understand what they are paying for. Business managers should then, in consultation with IT managers, determine the appropriate level of service at a price they can afford (Ross & Weill, 2002).
5. What level of security, and risks to privacy are the company prepared to accept. Security, like reliability and responsiveness, is a feature of IT systems that requires companies to weigh the level of protection they want against the amount they are willing to spend. Increasing security involves not only higher costs but also greater inconvenience (Ross & Weill, 2002). As global privacy protections increasingly become mandated by government, security takes on a new importance. It is up to



senior managers to assess the level of security required. Many IT units will adopt a philosophy that absolute security is its responsibility and will simply deny access anytime it cannot be provide safely (Ross & Weill, 2002).

6. Who are the people to blame if an IT initiative fails? The recurring concern from executives is that if IT efforts fail to generate the intended business benefits, the failure is often accompanied by some finger-pointing at the IT department. Surveys have found that the problem is often in the way non-IT executives are managing IT-enabled change in the organisation (Ross & Weill, 2002). To avoid disasters, senior managers need to assign business executives to take responsibility for realising the business benefits of an IT initiative. These “sponsors” need authority to assign resources to projects and time to oversee the creation and implementation of those projects. They should meet regularly with IT personnel, arrange training for users and work with the IT department to establish clear metrics for determining the initiatives’ success. Such sponsors can ensure that new IT systems deliver real business value; blaming the IT department reflects a misunderstanding about what the department can deliver. Companies should not approach IT decision making in an ad hoc manner. Companies increasingly are establishing formal IT governance structures that specify how IT decisions are made, carried out, reinforced, and even challenged (Ross & Weill, 2002).

Marcus (2006) feels that many companies treat the purchase of computer systems like the purchase of a commodity which can be a costly mistake. Software companies differ from other vendors that companies deal with. The stakes are high in any IT software purchase, as a failed IT project can put a company out of business.

Marcus (2006) lists some valuable considerations for companies to decide on before undertaking a major software implementation.

- A software implementation is a collaborative effort between the software vendor and the customer. Both are partners in the endeavour and must bring knowledge and skill to the table, together with a commitment to spend the necessary time and human resources to ensure a successful implementation.

- Clear and open communication is essential.
- Communicate the company's objectives to the software vendor.
- Listen to what the software vendor tells the company about the software's capabilities and shortcomings.
- A common reason for the failure of software implementation is the misunderstandings that develop between what the customer expects and what the software vendor can deliver (Marcus, 2006).
- The company's goal should be to tie payments to the achievement of milestones in the implementation process. The company should hold a substantial amount back until the solution had been tested and accepted (Marcus, 2006).
- Professional services should also be provided for in the contract. Normally the software vendor will provide a licence agreement with provisions that include ongoing support and maintenance, but the contract may include little if anything about implementation services.
- Companies should ensure that the contract spells out the responsibilities that the software vendor will bear and also build in protection against the price and timeframe getting out of hand (Marcus, 2006).
- The contract should define service levels that must be met for the implementation to be considered complete, and also for ongoing maintenance services. If the scope of the licence is limited, for example, by the number of users, a company should attempt to build in price protection for expanded usage in the future (Marcus, 2006).
- Software licence transactions can be complicated, and the price tag for the software is not always commensurate with the level of risk involved. Due diligence on the front end is essential. With the right attitude and the negotiation of appropriate contract protections up front, the company can minimise the risks associated with new software implementation and maximise the likelihood of success (Marcus, 2006).

McDowell (2005) is of the opinion that the problem regarding installation of the available MES solutions is not one of the technology that is available but of people. In many operations two IT departments have evolved over time, one addressing business processes and the other managing information on the shop floor. The latter is not often seen as critical for the IT

department and they need to be convinced otherwise. Similarly the financial people only really look at their reports on a monthly basis and do not believe that there is a need to look at what is happening on the shop floor in real-time. They need to understand the benefits of being aware of real-time activities. Many MES providers now establish a benchmark before and after installation, and the comparative figures have astounded top level management.

The production and engineering departments realise the benefit of having an MES solution. This message is poorly communicated to top management. It cannot be emphasised enough that people from IT and accounting, to instrumentation and engineering need to get together and talk. What companies must do to be successful is to establish a set of business objectives and then find out what makes these happen at shop floor level in real-time. As an example, if quality is an issue this would be one of the core parameters to measure at every stage of production. An early alert to a quality problem prevents additional costs being added to a product that has finally to be discarded. Similarly, in the plant there are only a few pieces of critical information required and these would be different at all levels from plant floor right up to top management. Another major advantage is that automatic information is truthful (McDowell, 2005).

According to Turbit (2005) most of the negative issues associated with the implementation of an MES solution are either technical issues or business issues, which can be managed if they are identified soon enough. Training can show people the impact of their actions in other areas of the business. QA programs can focus on quality of data. What most managers who have been through an ERP implementation have experienced is that the biggest impact is on corporate culture. The impact is always underestimated and never overestimated. Corporate culture is a combination of, on the one hand, the type of people who are employed by the company and their personal values, skills and habits, and on the other hand, the way the organisation works, the focus, decision making process, attitude to staff and stability. Both feed off one another.

Turbit (2005) emphasises the fact that for an organisation to successfully implement a MES solution; it needs to pay attention to consistency or accuracy and detail. Another dimension to

culture change is the timeframe in which the change is to be made. Training and preparation cannot prepare people for reality. Training and preparation will make the earlier transition easier, but will not remove all barriers. People will accept the system once they realise the benefits of a good system and the functional improvements compared to the current system.

## **2.6 The costs associated with an MES implementation.**

Software license transactions can be complicated, and the cost of the software is not always commensurate with the level of risk involved. Due diligence ahead of the implementation is essential: Companies can find itself over budget for a mission-critical application, stuck in a process with no end in sight. Upfront negotiation of appropriate contract protections can minimize the risks associated with new software implementation and maximize the likelihood of success (Marcus, 2006).

MES system costs are not slinked to the plant size or the foundry's production volume. Often a per-user or per-workstation cost is used to determine the solution cost. MES systems that run on large main-frame / mini-frame types of hardware have significant costs and support requirements that are independent of the MES software implemented on them. These costs are very similar whether running the new billion dollar laboratory or the 50 million dollar laboratory (McDonough, 2006).

When a plant purchases a piece of production equipment, that equipment has an inherent ability to produce product. The costs are leveraged by the capacity to produce. Buy more equipment and produce more products. A typical implementation of an MES system has large up front and underlying support costs that are for the most part in no way related to plant capacity. And here in lies the problem for most mid size and smaller facilities. How do they justify the very large installation / implementation / support costs when they are paying a price that is similar to that paid by a larger foundry producing five times more product than they are? On the other hand how do they dare not implement? Many medium sized or smaller laboratories run with in-house developed systems or no systems at all rather than incur the costs of a typical MES implementation (McDonough, 2006).

Installing an MES takes a cooperative, interdisciplinary effort by all departments. It is not just manufacturing's purchase but it affects information technology and quality assurance as well. Vendors also warn that the purchase price of an MES is \$500,000 and up, and this is only one part of its total cost. Company departments might have to change processes and install networks. Procedures need to be reviewed and streamlined, and documentation needs to be converted into electronic form. Machine controllers often need to be upgraded so a PC can integrate to them. The cost of redoing procedures can comprise 25% to 50% of the total MES installation cost (Seeley, 1997).

Then there is the cost of validation. Validation amounts to 40% of the installation cost. To help ease the validation process (the tests, protocols, reviews with vendors for software good practices), MES vendors guide medical device companies through it (Seeley, 1997).

The benefits of implementing an MES solution are well-known and well-documented (Fraser, 2004). But it may be difficult to persuade the management of a company to part with hard earned profits for a new system. A cost analysis is an effective way for a company to decide its purchasing price for a new system (Sage Software, 2005).

Software costs include software purchase or lease, maintenance fees and add-on products or packages required to adapt the system to the company's needs. These costs range from about \$7,500 (R60,000) to \$100,000 (R750,000) for purchase, with annual maintenance costs starting at approximately 15% of the purchase price (Sage Software, 2005)

Hardware costs include computers, components, networks and printers. Costs can be difficult to project until the software selection has been made. The company probably has all the hardware needed, but may need to upgrade servers or storage devices to accommodate the new system. For each 25 users the company should plan to spend \$7,000 (R50,000) to \$10,000 (R75,000) to upgrade existing equipment, and \$50,000 (R350,000) to \$65,000 (R500,000) if the company is starting from scratch (Sage Software, 2005).

The company will want an experienced consultant to help them select and plan the system implementation. Consulting fees vary regionally and the costs depend substantially on whether the company desires to do it itself or decides to off-load excess work to an expert. On average for an MES implementation, a company should plan on 1000 hours or more, with rates ranging from \$ 90 (R350) to \$ 180 (R 1,350) per hour (How to choose a Manufacturing System, Sage Software). Overtime costs will occur during implementation as staff will have more work than usual. The company might have to hire temporary employees to handle some administrative tasks or ask for overtime from its employees. Here the company should plan on 10 to 20 extra hours per week per 25 employees served by the new system (Sage Software, 2005).

Companies need training to get people up and running on the new systems. Good training is a logical investment in the success of the project since it can save many hours of expensive backtracking. Training costs are lower thanks to internet virtual classrooms that reduce travel time and fit education into busy schedules (Sage Software, 2005).

Companies should negotiate the payment terms. Most software companies will accept a progress payment format. The goal should be to tie payments to the achievement of targets in the implementation process. For example, the company will want to limit the investment in the project before the details are settled in a project plan or specification document. The company will want to hold off on final payment until the solution has been tested and accepted. The software vendor legitimately needs to be paid for its work at mutually agreed upon points in the process. But if the vendor wants too much of the license fee paid early in the contract, this is a sign that what the vendor really wants is leverage (Marcus, 2006).

## **2.7 Risks and challenges of implementing a MES solution.**

Since Advanced Manufacturing Research coined the term Integrated MES, there have been many attempts at implementing manufacturing execution system solutions. Unfortunately, many of these attempts have failed. The failures have been caused by many different reasons (Bruhn, 1997).

Integration remains one of the top challenges. The ability to proactively manage supply and demand remains an elusive goal for most manufacturers. Achieving this goal requires a shared understanding of priorities, visibility into manufacturing operations and the ability to commit to customers in real-time. Given the multitude of systems and technologies that most manufacturers own, it is no surprise that 63% report that they have difficulty integrating systems to provide this capability (Biddle, 2006). In addition to dealing with integration challenges, local IT teams can be overwhelmed when it comes to both the number and technical nature of the multiple applications that require support (Biddle, 2006). Each application is designed to support a specific function with its own unique data model, user interface, and development environment; any thought of integration came well after the design phase. Another promise of SOA is that each component application is designed with standardised integration links built into the component, which should greatly ease the integration burden that is so acutely felt throughout manufacturing (Biddle, 2006).

According to McClellan (1997) some MES projects fail, not because of computer or software malfunction but most frequently, from poor definition. Extensive customisation of the software can lead to various problems including errors in the system and serious integration problems with the other systems from which it needs information. Several approaches to shop floor data integration are slowly emerging. But there is another obstacle companies have to be aware of.

To the IT department, the cornerstone of efficiency is standardization. If a corporation has multiple manufacturing facilities this can mean, different platforms and software packages. That is complexity, and complexity uses time and money. The IT department's natural reaction, particularly in the wake of an ERP implementation, is to draw up a standards list that includes the shop floor and that requires everyone to follow. This could be detrimental for the organisation. The real challenge for the IT department is to draw the facilities into the architecture of the enterprise and provide a relatively standard set of integration tools, while still allowing each facility to optimize its own operating efficiency.

To improve internal relations, IT departments have to tighten their own links to factory or facility leaders, not only through meetings and committees but also by walking the shop floor to see the systems and processes in action. At Dentsply, IT staff includes training and implementation managers who, with factory managers, determine data and interface requirements and feed that information back to the central development group, then manage the rollout of the resulting systems (Slater, 2000).

Such communication allows IT departments to understand and weigh the benefits of standardization and the need for individual factory software tools and connectivity requirements. Making the right decisions depends on relationships with the factory staff. Issuing a mandate that forces all factories to run on a specific MES system X could be detrimental, without understanding the connectivity issues and the individual needs of each manufacturing operation. AMR's Swanton claims that many factory managers have a letter in their desk drawer saying that if they are forced to implement a system, they will resign (Slater, 2000).

## **2.8 Choosing the right MES solution.**

Once corporate management approves the implementation of an MES, the next step is choosing a software package. A good selection process starts with the creation of a cross-functional team tasked with developing business requirements that will be used to evaluate alternatives. These requirements will be matched up with specific features of the products under consideration. Specific requirements are more helpful in the selection process than general ones, which may be met to some degree by all the contending software packages, making it difficult to choose between them.

The team tasked with developing business requirements will be able to focus exclusively on the job for a certain period of time. A team that goes off-site for a week for the sole purpose of producing a list of business requirements will probably do a much better job than a team that must develop requirements during a series of one-hour meetings held over a period of days or weeks (Knight & Lamb, 2006). Once developed, business requirements should not be



inflexible. The team should be open to adding requirements in response to information acquired during the selection process. While viewing product demonstrations, for example, the team may discover that a couple of the competing software packages meet a corporate need that no one thought could be met by the package being considered. When the team learns that a need can be met, that need should be added to the business requirements used to evaluate the products (Knight & Lamb, 2006).

Once all the business requirements are known a request for proposal (RFP) should be issued to the vendors. A RFP is a business requirements scorecard which contains detailed information about the company's business requirements and the detail in which the MES solution is expected to deal with these requirements. Each requirement on the RFP will be weighted in some way and there will be a minimum threshold eg: 75% score for a vendor to qualify and be considered. The RFP is usually the first round for vendors to qualify towards the shortlist and finally having the project awarded.

Demonstrations of the competing MES products should be viewed by a large group from all areas of the company. Besides providing diverse input that will improve the selection process, the members of this group will get information about MES that will be useful when the selected system is installed. For example, manufacturing routing concepts such as workflow will likely be explained, and personnel can see how work flow can be configured using an MES. When evaluating products, the group should focus on key attributes such as out-of-the-box functionality, which is what the software is designed to offer without custom coding by the user. Examples of out-of-the-box functionality include end-user configuration of work flows and specifications, integrated non-conformance management, electronic signatures, user interfaces that direct operators and minimize data entry, and reports that are easy to read and configure. If an application requires custom code for such features, it will probably rank low in out-of-the-box functionality (Knight & Lamb, 2006).

An MES application will need to be validated for its intended use, e.g., in the manufacturing plant. The vendor should supply tools that will accelerate validation. These tools include the documentation, procedures, and validation protocols that help ensure that the quality systems

and production processes leveraging the MES are operating efficiently and comply with the latest FDA guidelines and regulations (Knight & Lamb, 2006).

If a data field includes upper and lower limits that can be set by users without custom coding, the field is said to be configurable. In general, people evaluating MES software should look for a system with many configurable features rather than one that requires coding to customize it for a particular application (Knight & Lamb, 2006).

Besides comparing the different MES products, the selection process should include an assessment of the software vendors. The company should ensure that the vendor whose software they are considering is a solid company with many years experience in developing and supporting MES software solutions. The vendor's people should be helpful and easy to work with as the company may be depending on this vendor for the next five to ten years. The company should also evaluate how much experience the vendor has had with regulated manufacturing firms (Knight & Lamb, 2006). Further investigation should be done into their software design and if their software is designed, developed, and released in a controlled process. The vendor should have recent, satisfactory audit results. The references that the vendors supply should be visited and interviewed. Feedback from other manufacturers is essential (Knight & Lamb, 2006).

When all the selection information is collected and collated, it is time to make a choice. In all probability, each system will have both strong and weak points. So it may be helpful to use a scoring system, similar to the scoring system used in the initial RFPs, to rate the options according to the organisations requirements. Scores can be based on how good each option measures up to the business requirements required, ranked in order of importance (Knight & Lamb, 2006).

## **2.9 MES implementation strategy and methodology.**

With the selection process concluded, the equally important process of MES implementation begins. In most cases, implementation takes place in phases. The implementation team should decide how to phase in an MES. Like the team that developed the business requirements, the

implementation team should be a cross-functional group that includes representatives of all key departments of the company, including IT, manufacturing, and quality. The team should also include project managers from the manufacturer and the software vendor (Knight & Lamb, 2006).

The following eight steps form the basis of the MES implementation (Approach and Methodology of TATA Consultancy Services).

- The first step is a thorough assessment of the state of the company's manufacturing process and the intended area where the MES solution is to be implemented. Once this has been completed the consultants will have a good idea about the process improvements that are possible.
- The second step is a full analysis of the information requirements of the company. This is a long process and involves many interviews with the various interested parties and an analysis of the information requirements of other IT systems like the ERP system.
- The third step is to map out the full decision process and analyse it. This will help the consultants to set up the hierarchy when implementing the software.
- In the fourth step of the process the consultants start designing a high-level solution to get an idea of all the facets and requirements of the required solution.
- The fifth step is to find the most suitable solution that fits the company requirements completely. Often a combination of two or more solutions to meet the requirement is needed and in some cases some parts of the solution need to be built.
- The sixth step of the process is the deployment of the solutions. This is where the MES solution is implemented.
- In step seven the implemented solution is tested and analysed to ensure that all the integration lines work and that the system is performing to the specifications originally **set**.
- The eighth and final step is to set up a continuous improvement strategy whereby the information received from the MES system is used to improve the processes and eliminate all waste (TATA Consultancy Services, 2002).

To aid in the implementation of MES products and systems, CIMNET, a group of trained engineers who aid organisations in the implementation of MES solutions, have developed effective methodologies to guide projects through their key phases.

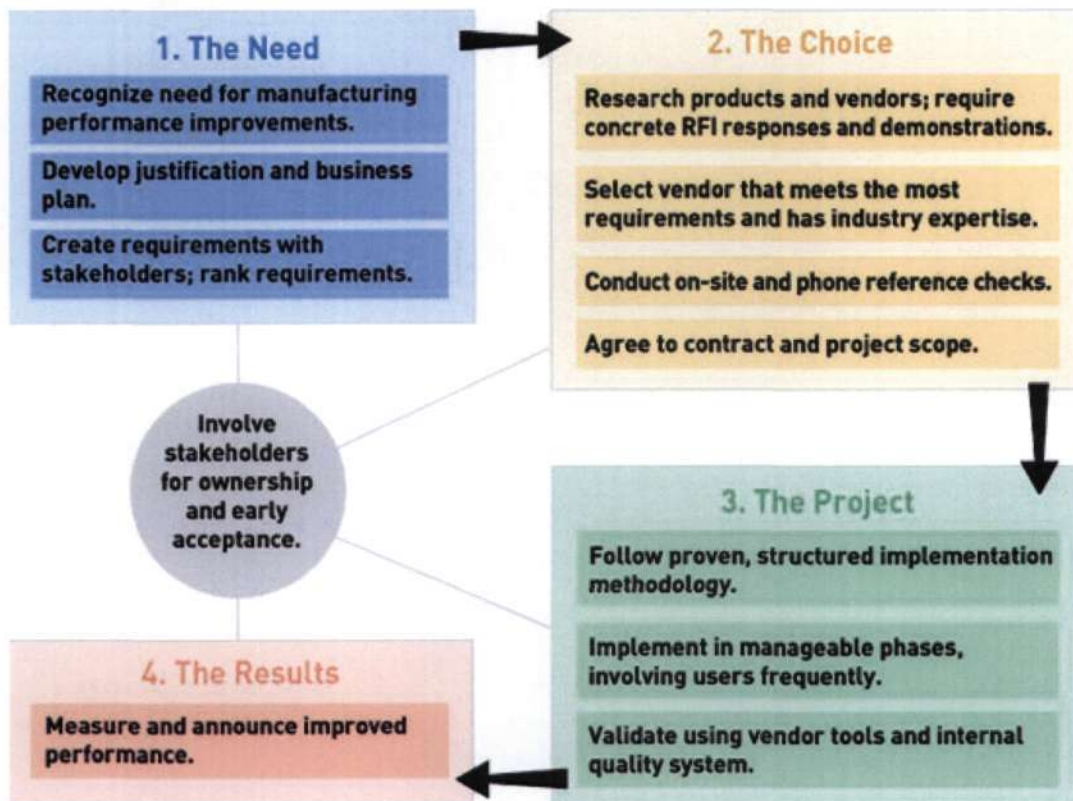
1. The original project definition where the whole project is defined and documented in a project plan.
2. The expected return on investment (ROI) is also defined.
3. Assurance of commitment from all parties involved, including management. Without this assurance the project is already on the wrong path.
4. Announcing the MES project team management and their specific areas of the project. Each of these members will take responsibility for a small team tasked with one or more of the facets of the implementation.
5. The design and creation of interfaces to the ERP, document, labour and other systems from whom information is required.
6. The development of a functional MES solution.
7. The software and database installation and configuration.
8. Training of the staff and completion of all implementation documentation and manuals (CIMNET, 2005).

Outsourcing the implementation of software saves time and reduces the number of setbacks when compared within-house implementation (Cosgrove Ware, 2003). As a result, when a company outsources, the number of software units implemented is greater and the time needed to implement those units is reduced. It is therefore important to go with an expert when deciding to outsource an implementation. Furthermore it is recommended to outsource incrementally. Before outsourcing projects to third parties get references from peer companies (Cosgrove Ware, 2003).

### **2.10 The implementation of the MES solution.**

Before realizing the benefits of an MES solution as discussed in 2.4 of this chapter, a company must follow each step in the implementation process to be successful. Key steps along this road include choosing the right MES product and implementing the system at the company.

These steps significantly affect the gains that come from computerized recordkeeping as can be seen in the chart below.



**Figure 2.3** MES implementation – basic steps

Knight, J. & Lamb, S. 2006. Selecting and Using a Manufacturing Execution System. *Medical Device Link* [Online].

In the chart above Knight and Lamb (2006) show the basic steps to a successful MES implementation. They start with The Need, recognition of the need for manufacturers to improve their production performance in the face of constant competitive pressure. This is followed by the development of a full cost and benefit justification and business plan for the implementation of the said MES system. Further, meetings must be held with all the stakeholders to determine each of their requirements and information needs from the MES system.

The Choice consists of the vendor selection process which includes the product and vendor research, request for information (RFI) responses and live product demonstrations, the

checking of vendor references and the agreement of the contract and the full scope of the project (Knight & Lamb, 2006).

Here the MES solution is implemented following the structured implementation methodology as agreed on in the planning phase. An approach where all the MES functionality is implemented at the same time should be avoided; instead an approach where the implementation is done in small manageable phases in which the end-users are frequently involved should be adopted. Small wins that occur often are much better for morale than striving for one big win that will come in 18 months. The final step is to validate the implementation by using the vendor's tools and the internal quality system (Knight & Lamb, 2006).

The Result is when the performance of the plant is measured after the implementation and compared with the results before the implementation and there is a huge improvement. Key to the whole process described above is the involvement of stakeholders and end-users. It is vital to the success of the implementation that these people are positive throughout the implementation (Knight & Lamb, 2006).

Knight and Lamb (2006) state that typically, companies start by implementing features that will meet the minimum requirements set by the company for an MES solution. The second phase can include additional data collection and controls to reduce variability and increase throughput. The third phase adds the analysis of this new breadth and depth of data to continually improve processes.

A concurrent approach is to implement each phase by product line. Most companies start with a challenging product line for which streamlined processes will provide the greatest benefit. Examples include a product whose manufacturing processes or bill of material are complex and difficult to track on paper, or a product whose volume is increasing and would be slowed by continuing to use paper, or a product whose yields or field failures are not at desired levels. One of the most important and most difficult tasks for the implementation team is educating staff about the MES solution. The capabilities of manufacturing software can be hard to grasp

for people used to conventional recordkeeping tools. But learning will eventually lead to buy-in as people begin to understand what an MES solution can do for them (Knight & Lamb, 2006).

The implementation team can boost buy-in by getting input from users on how the software should be configured. For example, the team can ask operators to test a user interface and suggest ways to improve it. Or the team can ask engineers to critique an MES report format. By soliciting and acting on this type of feedback, the team gives company personnel an ownership stake in the MES project. Buy-in aside, this feedback is valuable because it helps the team make the system easier to use.

Validation will be required, and the implementation team must plan for it. The plan will include the scope, assumptions, roles and responsibilities, and acceptance criteria. Thorough requirements must be documented, including user requirements and functional requirements. These are the baselines for the traceability matrices used in the software qualification test protocols: installation qualification (IQ), operational qualification (OQ), and performance qualification (PQ) (Knight & Lamb, 2006).

Regulated companies should operate the electronic system in parallel with the old system for a limited time (PQ), to prove that its results are equal to, and often better than, the old system's results. If end-users have been involved throughout the implementation, the duration of parallel processing is often short, because issues have already been exposed and resolved. In any case, it is advisable to use a risk-based approach, in which the validation process is thorough and verifiable, but does not overburden the effort with excessive interpretation of the regulations. Among companies switching to computerized data-collection systems, a common concern is what happens if the system is off-line. Many companies can't afford manufacturing downtime caused by an MES malfunction. Understandably, however, these companies don't want to back up their electronic recordkeeping system with an extensive paper-based system like the one they're replacing. So the implementation process should include the installation of redundant systems that ensure 100% uptime and data integrity. That is, if one system fails, there can be a seamless switchover to the other without any production downtime (Knight &

Lamb, 2006). Disaster recovery procedures like daily backups and periodic data movement to a separate database is essential.

### **2.11 MES implementation partners (SIs) and consultants.**

Companies that outsource packaged-software implementations can benefit from shorter time to implementation and lower costs when compared with taking on these tasks in-house. IDC, one of the global providers of market intelligence, advisory services, and events for the information technology sector, estimates that the time to implement an application can be reduced by 43 percent if performed by an outsourcer because of its superior experience in an application area and more effective cost and resource management. In the short term, hiring additional personnel reduces productivity of existing employees due to training and assimilation. When a company outsources, the application outsourcer absorbs these risks and can maintain a steady level of productivity (Cosgrove Ware, 2003).

The success rate of MES implementations is certainly increasing. One major reason for this is the emerging role of independent MES systems integration and consulting firms. The truly independent, qualified systems integrator brings not only a wealth of manufacturing process knowledge, but also a broad perspective with regard to the major relevant MES and companion technologies necessary to enable a profit improving solution. This is why the first step toward implementing a successful integrated MES solution is to select and retain the right MES systems integration and consulting firm (Bruhn T, 1997). Proven experience is definite prerequisite for any systems integrator. The selection process for choosing the right systems integrator should begin with a firm that can display proven experience with MES. The firm must approach the market from a completely neutral position. This way the client can truly "lead with the need", not with the technology (Bruhn, 1997). Additionally, the systems integrator should have extensive business as well as manufacturing process experience within the specific market for the target client. This experience is necessary to fully understand the operations and how they can potentially be improved.



Similarly, a broad familiarity with the major software solutions and their functionality is helpful. There are already numerous software companies with MES solutions and others are emerging rapidly. The systems integrator must be able to muster solutions across a broad range of the client's hardware platforms, operating systems, and databases. The systems integrator must have the necessary experience with all the various integration tools to bring the solution together in the most expeditious manner (Bruhn, 1997).

Any successful implementation will require integration into companion technologies such as Production Information Management Systems, Laboratory Information Management Systems, and Enterprise Resource Planning Systems. It is thus important that the systems integrator understands the organisations business, the production processes, and the most effective tools to facilitate effective integration in the most effective possible way. Finally, because the real-time world of process control is so different from the transaction-based environment that exists at the business systems level, the right systems integrator must also be experienced with the millisecond world of process control (Bruhn, 1997).

Again, experience is the key to successfully implementing MES. It is very important that the systems integrator has a broad base of experienced systems engineers and will not put inexperienced people on the job. An MES implementation is no place to gain process experience. The top firms are able to display solid reference sites that will testify to the calibre of the systems integrator and the profit improvement that they helped create. A reference site is also a great place to inquire about the systems integrator's project management skills and implementation methodologies (Bruhn, 1997).

## **2.12 Integration of MES solutions with other systems in the organisation.**

The MES is at the centre of the enterprise's fulfilment cycle, where ideas and raw materials connect to produce value for the customer. As such, the MES can provide the greatest benefit for the enterprise through its potential to link with the critical pieces in the enterprise. Maximum value is achieved where there is some degree of integration between the systems that control the finance, the supply chain and the manufacturing processes, in order to support cross-functional businesses and information flows (Cagna *et al.*, 1999).

The MES can consolidate and right-size data for other systems, such as the ERP system and the APS. For example, linkage between the MES and APS provides the translation of demand forecasts into production requirements that make the APS plans truly effective, using accurate, real-time data on plant capacity and its sub-elements. System integration can also allow automatic scaling and sequencing of recipes and specification of raw material requirements, consistent with demand forecasts. Quality data feedback from the MES to the APS can enhance demand forecasting. Linkage of financial and production reporting can greatly improve strategic understanding of business operations. Realistic information on costs and effort enables more accurate product planning, while accurate plant performance information improves sourcing decisions and maximizes profit (Cagna *et al.*, 1999).

Standard interfaces for an MES are necessary to solve the integration problems in a heterogeneous environment. The standard interfaces usually evolve from a series of three stages. In the first stage, developers of a software system develop the specification of proprietary, vendor-specific interfaces. They are different from one system to another. Users/integrators have to develop translators for exchanging data between any two different systems. Consequently, the integration cost to software users is usually high. To alleviate the problem of interface incompatibility, some users and vendors join a consortium to develop a common set of interfaces which is sharable among users and vendors (Feng & Shaw, 2000). This set of common interfaces is a product in the second stage. Common interfaces usually lead to some reduction in the cost of integration. However, different consortia may develop different sets of interfaces that are often incompatible for the same application domain. More users and vendors realize the need to create standard interfaces based on consensus on the international level. Users, vendors, and researchers jointly develop interface standards, which are open, neutral, and internationally accepted (Feng & Shaw, 2000).

### **2.13 Requirements for next generation MES solutions.**

The manufacturing enterprises of the future will be in an environment where markets are frequently shifting, new technologies are continuously emerging, and competitors are multiplying globally. Manufacturing strategies should therefore shift to support global competitiveness, new product innovation and introduction, and rapid market responsiveness.

The next generation manufacturing systems will therefore be more strongly time-oriented, while still focusing on cost and quality. Such manufacturing systems will need to satisfy some basic fundamental requirements (Shen & Norrie, 2006). In order to support global competitiveness and rapid market responsiveness, an individual or collective manufacturing enterprise will have to be totally integrated with its related management systems (e.g., purchasing, orders, design, production, planning & scheduling, control, transport, resources, personnel, materials, quality, etc.) and its partners via networks.

For effective enterprise integration across distributed organizations, distributed knowledge-based systems will be needed to link demand management directly to resource and capacity planning and scheduling (Shen & Norrie, 2006). Such manufacturing systems will need to accommodate heterogeneous software and hardware in both their manufacturing and information environments. Heterogeneous information environments may use different programming languages, represent data with different representation languages and models, and operate in different computing platforms. The sub-systems and components in such heterogeneous environments should interoperate in an efficient manner. Translation and other capabilities will be needed to enable such interoperation or interaction. It must be possible dynamically to integrate new subsystems (software, hardware, or manufacturing devices) into, or remove existing subsystems from, the system without stopping and reinitializing the working environment. This integration will require open and dynamic system architecture (Shen & Norrie, 2006).

Manufacturing enterprises will have to cooperate fully with their suppliers, partners, and customers for material supply, parts fabrication, final product commercialization, and so on. Such cooperation should be in an efficient and quick-response manner. People and computers need to be integrated to work collectively at various stages of the product development, and even the whole product life cycle, with rapid access to required knowledge and information. Heterogeneous sources of information must be integrated to support these needs and to enhance the decision capabilities of the system. Bi-directional communication environments are required to allow effective, quick communication between humans and computers to facilitate their interaction (Shen & Norrie, 2006).

Considerable attention must be given to reducing product cycle time to be able to respond to customer desires more quickly. Agile manufacturing is the ability to adapt quickly in a manufacturing environment of continuous and unanticipated change and thus is a key component in manufacturing strategies for global competition. To achieve agility, manufacturing facilities must be able to reconfigure rapidly and interact with heterogeneous systems and partners. Ideally, partners are contracted with "on the fly" only for the time required to complete specific tasks (Shen & Norrie, 2006).

Scalability means that additional resources can be incorporated into the organization as required. This capability should be available at any working node in the system and at any level within the nodes. Expansion of resources should be possible without disrupting organizational links previously established. The system should be fault tolerant both at the system level and at the subsystem level so as to detect and recover from system failures at any level and minimize their impacts on the working environment (Shen & Norrie, 2006).

#### **2.14 Research Questions.**

The following research questions are aimed at organisations that have successfully completed an MES solution implementation.

- What were the key drivers behind the organisation's decision to implement an MES solution and did the solution deliver the anticipated results after the implementation?
- Which implementation strategy/methodology was favoured by these companies with regard to system functionality, systems interfacing, implementation challenges/risks, evaluating a solution, implementation partner, change management, implementation costs and future requirements?
- What obstacles were encountered during the process and how were they overcome?
- Which parts of the MES implementation process, if given the opportunity, would have been done differently and for what reason?

## **2.15 Conclusion.**

The MES system bridges the gap between the planning system and the control system using on-line information to manage the current application of manufacturing resources: people, equipment and inventory. MES solutions have shown some incredible returns for the companies that have successfully implemented the solution (MESA). Most organisations claim full return on investment in nine to twelve months. There are a number of issues around integration, costs, software vendor, change management, implementation and future developments that need to be considered before embarking on an MES implementation.

Organisations that have implemented 80% of an MES solution will find that the real value lies in the last 20% of the implementation. An unsuccessful implementation is a very costly affair for any organisation. Due to the complexities involved with MES implementations, like systems integration, software fit, reporting requirements, multiple applications etc. it is almost better and cheaper to start from the beginning rather than try to fix an implementation that was unsuccessful. This is an opportunity that very few organisations could afford and few shareholders will allow. Most organisations have to have a successful implementation the first time.

Doing research into all the various issues that need to be considered when implementing an MES solution takes a considerable amount of time, which is something that a senior employee in a large organisation does not have much of. Studying the various implementation strategies and methodologies of the various consulting companies and MES vendors reveals that there are vast differences between them. More alarming is the fact that most of them specialise in certain areas or industries and do not provide a total implementation strategy and methodology that covers the whole spectrum. This dissertation aims to cover all the possible considerations that an organisation will have to consider before embarking on an MES implementation.

The next chapter will put the Research Methodology in context by discussing the types of data, the types of questions, validations, what type of data was collected, the questionnaire, population/sample and data handling.

## **Chapter 3**

### **Research Design and Methodology**

#### **3.1 Introduction**

In the previous chapter the literature was reviewed. This chapter looks at the practical aspects of the research undertaking. The research methodology that was applied in order to answer the research questions developed in the previous chapter will be discussed and put into context in this chapter.

The research questions arrived at were,

- (1) What were the key drivers behind the organisations decision to implement an MES solution and did the solution deliver the anticipated results after the implementation,
- (2) Which implementation strategy/methodology was favoured by these companies with regard to system functionality, systems interfacing, implementation challenges/risks, evaluating a solution, implementation partner, change management, implementation costs and future requirements,
- (3) What obstacles were encountered during the process and how were they overcome,
- (4) Which parts of the MES implementation process, if given the opportunity, would have been done differently and for what reason?

In addition this chapter will discuss the key motivations for the research, the types of data, the data collection method, the research instrument, the type of questions used, the validation of the data, the population sample, the data handling and finally the conclusion.

#### **3.2 Research Concept**

The key motivation of this research project was to develop a guide that could help companies that intend implementing a MES solution, to implement the solution successfully and within the planned timeframe and budget.

To achieve the outcome, the first step was to conduct an in-depth literature review on all available literature related to the implementation of MES solutions. This review provided a useful knowledge base on most of the intricacies of an MES implementation. This included the definition of an MES solution, the functionality of an MES solution, the costs associated with an MES implementation, the risks and challenges associated with an MES implementation etc.

Utilising the data from the literature review it was now possible to devise a hypothesis from which the research questions were derived. The hypothesis was derived from the underlying view that was perceived to be present in most of the literature reviewed. The perception was that most of the problems experienced during and after an MES implementation could have been avoided if the initial decision and planning and project scoping stage of the project had been completed properly. The hypothesis that was formulated is therefore – MES implementations that are not thoroughly planned and properly specified and scoped before the implementation commences and that are not driven from a very high level in the organisation will not be successful and the organisation will struggle to get a fully functional MES system implemented in the organisation.

The next step was to prove or disprove this hypothesis by evaluating the successful and unsuccessful MES implementations of as many companies, globally, as possible. The information for this evaluation was gathered by means of a questionnaire. The questions asked were based on the research questions which in turn are based on the perceived problem areas found in a MES implementation. By evaluating the responses to the research questionnaire the validity of the hypothesis could be established and a final conclusion could be reached.

### **3.3 Data Types**

In this type of research the data are from both a primary and secondary sources.

#### **3.3.1 Primary Data**

Lubbe and Klopper (2005) refer to the Wolfgang Memorial Library (undated) that define a primary source as first hand testimony or direct evidence concerning the topic under investigation. Thus all data collected through the research questionnaire that was emailed to

each of the respondents personally, is classified as primary data or data from a primary source.

### **3.3.2 Secondary Data**

Lubbe and Klopper (2005) state that a secondary source interprets and analyses primary sources. Saunders, *et al.* (2003) define secondary data as data used for a research project that were originally collected for some other purpose. They also define documentary secondary data as multiple source secondary data, survey-based secondary data. Finally Saunders, Lewis and Thornhill (2003) define secondary literature as subsequent publications such as books and journals. In this research project, almost all the data collected in the literature review can be classified as documentary secondary data and as secondary literature

### **3.3.3 Quantitative Data**

Saunders, *et al.* (2003) define quantitative data as numerical data that has been quantified (analysis conducted through the use of diagrams and statistics). Unfortunately there are very few examples of quantitative data in this research dissertation. Small fragments can be found in the documented gains (wins) that companies have had after successfully implementing an MES solution. Almost all of this data comes from publication of companies who specialise in research like AMR Group, Aberdeen Group, Foresters and MESA.

### **3.3.4 Qualitative Data**

Saunders, *et al.* (2003) define qualitative data as non-numerical data or data that has not been quantified (analysis conducted through the use of conceptualisation based meanings expressed through words). Most of the data in the literature review falls into this category as it is the findings of the authors that are expressed in words written into the literature.

## **3.4 Data Collection Method**

According to Saunders, *et al.* (2003), questionnaires can be used for descriptive or explanatory research, where descriptive research (such as that undertaken using attitude and opinion questionnaires) will enable the researcher to identify and describe the variability in different phenomena, while explanatory or analytical research will enable the researcher to examine and explain relationships between variables, in particular cause-and-effect relationships. The data



collected from the questionnaire will be collated and then analysed using various statistical methods like pivot tables, percentages of sample and graphs.

### **3.5 The Research Instrument (Questionnaire).**

(See appendix for a copy of the completed Research Questionnaire.)

#### **3.5.1 Introduction**

The research questionnaire is divided into five parts. The first part is the covering letter to the respondent listing the topic of the research, the name of the researcher, the supervisor, the qualification aspired to, the university and business school. This is followed by a short paragraph explaining the research and also that the research is voluntary and can be withdrawn at any time.

Part 1 of the research questionnaire covers the permission statement from the respondents giving their permission to use their response for academic research.

Part 2 covers the general questions about the organisation, the industry, vertical, status of their MES implementation, business improvement initiatives, MES functionality implemented and MES support functionality.

Part 3 covers the MES decision including the main drivers that made the company decide to implement an MES solution, and the involvement of various management levels in the decision.

Part 4 covers the implementation and the importance of certain functional areas in the organisation, the contract with the vendor, approximate cost, difficulty in researching certain goal posts.

Part 5 touches on subjects like implementation partners, benefits, future requirements and improvements achieved.

#### **3.5.2 Developing the Questionnaire**

The questionnaire was specifically developed to answer the research questions but also to provide evidence to prove or disprove the hypothesis. The first two research questions, 'what were the key drivers behind the organisations decision to implement an MES solution and did the solution deliver the anticipated results after the implementation and which implementation strategy/methodology was favoured by these companies with regard to system functionality, systems interfacing, implementation challenges/risks, evaluating a solution, implementation

partner, change management, implementation costs and future requirements' are covered adequately by questions 1 to 22.

The third and fourth research questions, 'what obstacles were encountered during the process and how were they overcome, and which parts of the MES implementation process, if given the opportunity, would have been done differently and for what reason', are covered by questions 23 and 24.

These are probably the two most important questions of the whole questionnaire as they are designed to point out the problem areas of each organisation's implementation. Question 24 highlights possible solutions to this specific implementation problem and gives a good idea of how it could have been avoided. These two questions are also significant to prove or disprove the hypothesis.

### **3.5.3 Types of Questions**

The questionnaire is made up of a box to tick, and boxes that need numbers from the keys and, boxes that need percentages, and finally two questions that need a short paragraph. The types of questions put to the respondents range from straight forward questions like "In which of the following industry verticals does your company fall" to questions where the respondent has to rate certain statements according to a specific key provided, for example, rating the key drivers for implementing an MES solution. The key consists of numbers from 1 to 5 with 5 representing Critical, 4 representing Very Important, 3 representing important, 2 representing Not That Important and 1 representing Not Important At All. The respondent then rated each statement according to his experience in his organisation's MES implementation. In the questionnaire there are several variations on the above question with the numbers 1 to 5 representing different meanings.

The final two questions (23 & 24) require a couple of lines or a small paragraph.

### **3.5.3 Validation of Data**

A test questionnaire was emailed to, Edmond Quinton, the MES specialist at Citect South Africa, for commentary before the questionnaire was finalised. The final questionnaire was sent to the ethics board at the university and full approval was received.

## **3.6 Population Sample.**

(For full list of population sample see appendix)

The population of the sample approached for this research was employees of organisations that were in the process of implementing MES or had completed an MES implementation. Only employees of these organisations, who were involved in the implementation, were approached.

A total of 560 questionnaires were emailed to 508 organisations in 57 countries worldwide. Of these questionnaires the bulk went to the USA (21%). Australia (16%), South Africa (8%), UK (6%), New Zealand (6%), India (6%) and then Spain, Canada, Sweden, France and China (3%) received the rest.

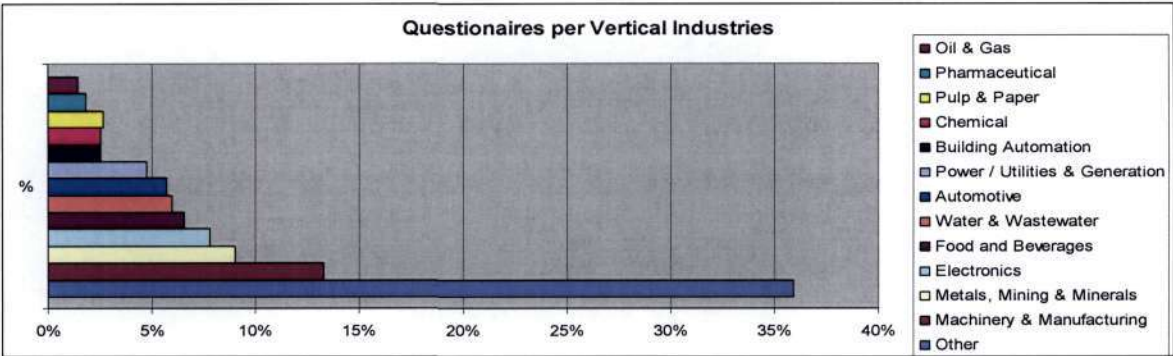


Figure 3.1 Research questionnaires per vertical industries.

Introduction to Figure 3.1: This is a vertical bar graph which depicts a breakdown of the various industries that the recipients of the research questionnaire fell into.

In Figure 3.1 the various participants were grouped into 12 vertical markets and an “Other” vertical was included. The Other vertical received 36% of the questionnaires while Machinery and Manufacturing received 13% of the questionnaires. Metals, Mining & Minerals received 9% while Electronics received 8%. Food and Beverage received 7% while Water & Wastewater and Automotive each received 6%. Power / Utilities & Generation received 5% while Building Automation and Chemical each received 3%. Pharmaceutical received 2% and Oil and Gas 1% of the questionnaires sent out. The reason for the distribution of this breakdown is due to the availability of the databases used and these percentages in no way depict market size of the industries or MES implementations by vertical industry in any way.

### **3.7 Data Handling**

No permissions were required to run this survey.

The questionnaire, in Microsoft Excel, was emailed to the personal email addresses of the selected participants. When the questionnaires were returned they were collated and analysed using Microsoft Excel.

### **3.8 Conclusion**

In the planning phase of the research design and methodology, due to the large amount of data that was expected to be received, it was decided that, the design, methodology, data types, data collection and data analysis would be kept as simple. Once the questionnaires were received back a format was applied that collated all the answers onto a one page table format.

The research concept was to design a straight forward, uncomplicated guide that all employees in an organisation, that intended to implement an MES solution, can understand and interpret correctly. This could help these organisations to follow a structured step-by-step approach to successfully implementing the required MES functionality.

Most of the data collected was primary data, collected directly from the respondents personally by means of a personal email with a questionnaire attached. There is also documentary secondary data collected through the books, articles, white papers and journals used in the literature review.

The research instrument used is a questionnaire that was developed to answer the research questions and prove or disprove the hypothesis. This questionnaire was sent to 560 selected individuals in 508 organisations, in various industry verticals based in 57 countries worldwide.

Chapter 4 discusses all the findings from the survey conducted. In Chapter 4 the findings are displayed in a graphical and statistical format. The answers received from the returned research questionnaire are also analysed.

## **Chapter 4**

### **Discussion of Findings**

#### **4.1 Introduction**

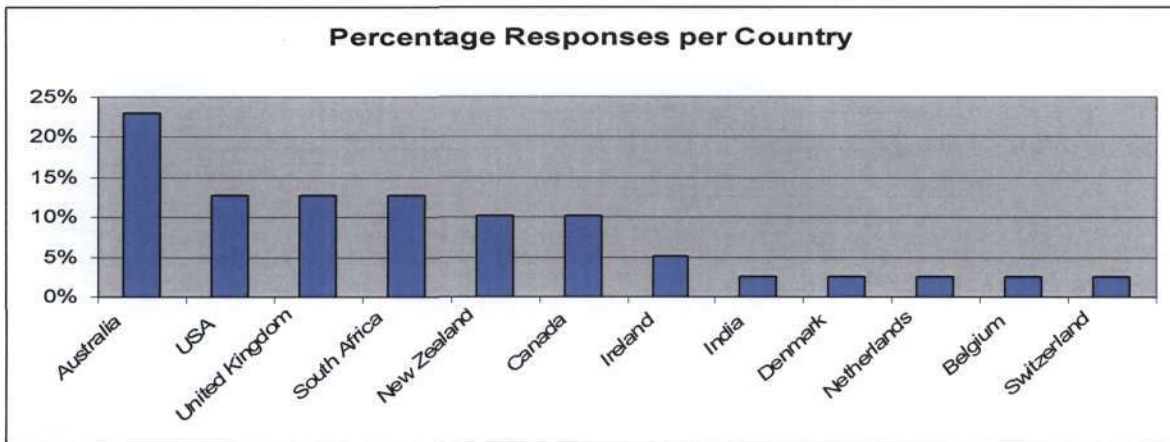
Chapter 3 defined the research problem and hypothesis. It also analysed the key concept of the research and looked at the various variables in this study. Chapter 3 discussed the various data types and data sources. There is a section that discusses the data collection method and a section that discusses the research questionnaire and its various sub-sections. Chapter 3 discusses the validation of the data, the population sample, and the data handling.

The purpose of the data analysis is to determine the MES implementation experiences that each of the respondents has experienced, in order to ascertain what problems and stumbling blocks were experienced during the MES implementation and what part of the implementation was uneventful and without problems. Chapter 4 determines if certain implementation problems are more prevalent in certain industry verticals than in others. Analysing all these questionnaires helped the researcher to arrive at a conclusion regarding the hypotheses after which he was able to make certain recommendations in Chapter 5.

#### **4.2 Demographic Description of Sample**

Below are the demographic statistics of the respondents to the research questionnaire that was emailed to each of the 560 respondents globally. Only 39 questionnaires were returned. It amounts to a response of less than 7% of the questionnaires sent out. The weak response is attributed to the fact that for approximately 50% of respondents English is not a first language. The questionnaires were emailed in the week of 26 November 2006 to 2 December 2007 and a contributing factor could be that most plants close over the festive season and these plants are under huge pressure in the run-up to this closing period to produce as much as possible before the close.

### 4.2.1 Responses per Country

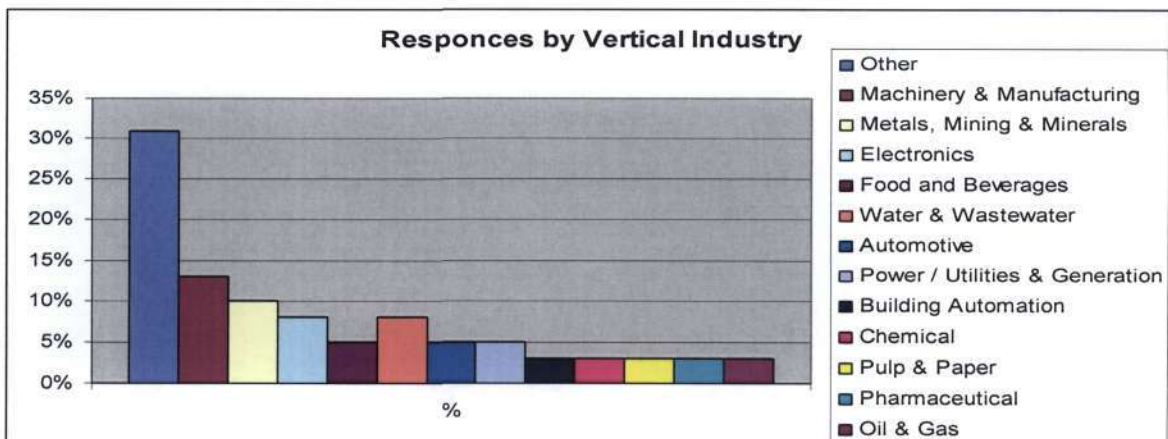


**Figure 4.1: Analysis of research questionnaire responses per country.**

Introduction to Figure 4.1: This is a vertical bar graph which depicts the breakdown of the analysis of the responses to the research questionnaire by country.

As could be expected most of the responses came from English speaking Western countries. Australia made up 23 % of the responses followed by the USA, the United Kingdom and South Africa with 13% of the responses each. New Zealand and Canada were each responsible for 10% of the responses and Ireland 5%. India, Denmark, Netherlands, Belgium and Switzerland each contributed 3% of the responses.

### 4.2.2 Responses per Industry Vertical

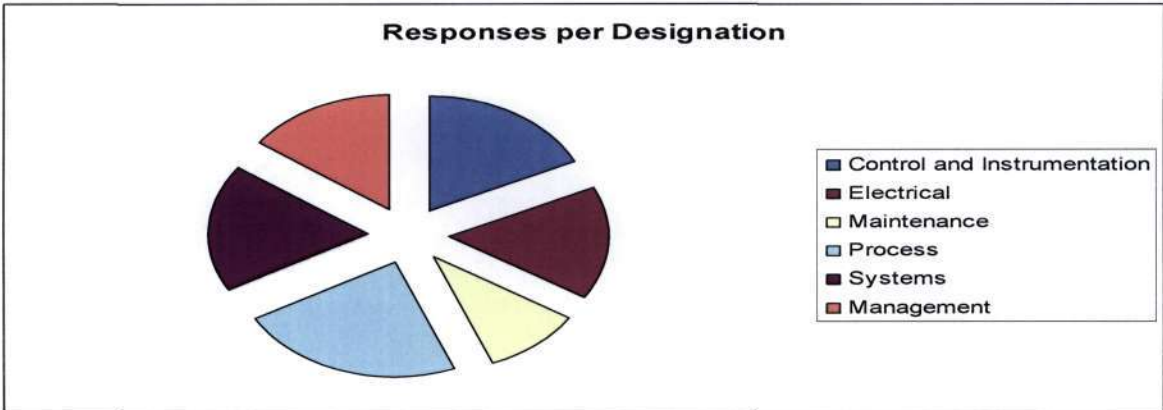


**Figure 4.2: Analysis of research questionnaire responses per vertical industry.**

Introduction to Figure 4.2: This is a vertical bar graph which depicts the breakdown of the analysis of the responses to the research questionnaire by vertical industry.

In this graph “other” industries are responsible for 31% of the responses. Machinery was responsible for 13% and Mining Organisations contributed 10% followed by the Water and Waste vertical with 8%. The Electronics vertical contributed 8% with the Power and Utilities, Food and Beverage and Automotive industry closely following with 5% respectively. Pulp & Paper, Pharmaceutical, Oil & Gas, Chemical & Building Automation each contributed 3%. In the analysis the correlation between the various industries is very close to the correlation of the industries to each other in figure 3.1 which depicts the questionnaires sent out per vertical industry.

**4.2.3 Responses per Respondent Designation**



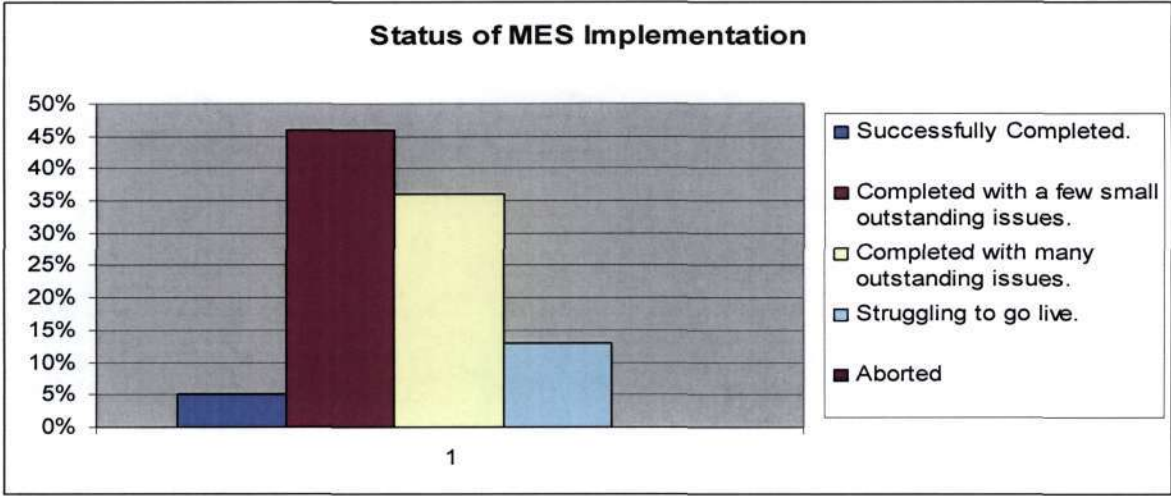
**Figure 4.3: Analysis of research questionnaire responses per designation.**

Introduction to Figure 4.3: This is a pie graph which depicts the breakdown of the analysis of the responses to the research questionnaire by designation of the respondents.

Of the 560 questionnaires emailed out to respondents, there were 242 different designations and the same can be said of the designations of the respondents who replied. To achieve an accurate indication of the area of expertise of the respondents their designations were grouped together into functional areas to enable the analysis of the function they specialise in. Respondents who were involved within the Control and Instrumentation function as either an engineer or technician made up 18% of the responses. Respondents whose function fell under

Electrical made up 15% of the respondents with Maintenance responsible for 10%. Respondents who were involved in Process made up 23% and respondents involved in Systems or IT made up 18%. The remaining 15% was made up by Management. Management in this context ranges from the Plant Manager up to the CEO. Maintenance Managers or Systems Managers were counted in their respective functional areas.

**4.2.4 Status of the MES Implementation**



**Figure 4.4: Analysis of research questionnaire responses by status of implementation.**

Introduction to Figure 4.4: This is a vertical bar graph which depicts the breakdown of the analysis of the responses to the research questionnaire by the status of the MES implementations in the respective organisations.

Figure 4.4 indicates where the respective organisations are in their project implementation lifecycle. Of the respondents only 5% had successfully completed their MES implementation. A large group (46%) had completed their implementation with a few small outstanding issues. A slightly smaller group (36%) had completed their implementation but still had many outstanding issues to resolve. A small group (13%) of respondents were struggling to go live and none of the respondents had aborted their implementations of the MES solution.



#### 4.2.5 Business Improvement Initiatives

Business improvement initiatives are methodologies that companies implement to help them improve various aspects of their production or mining processes. These initiatives work very well if implemented correctly but can take a long time, up to two years, before they start showing a return on investment.

Lean manufacturing which is used in 59% of the respondent's organisations is a methodology that has its origin in the Toyota factory in Japan under a manufacturing guru Taichi Ohno. Lean manufacturing aims to reduce waste in a process.

A recent study by management consultants Mckinsey shows that organisations that have followed business improvement methodologies (such as implementing lean) and invested in information technology (like MES) are performing alot better than companies that have implemented only one approach. The improvement in organisations that used business improvement only was 8% compared to the impact of investing in IT alone which showed a 2% improvement. Business improvement and IT provided a 20% improvement in productivity. While manual process achieved good results, adding automation and real-time data achieved much better results (Doran & Dowdy, 2004).

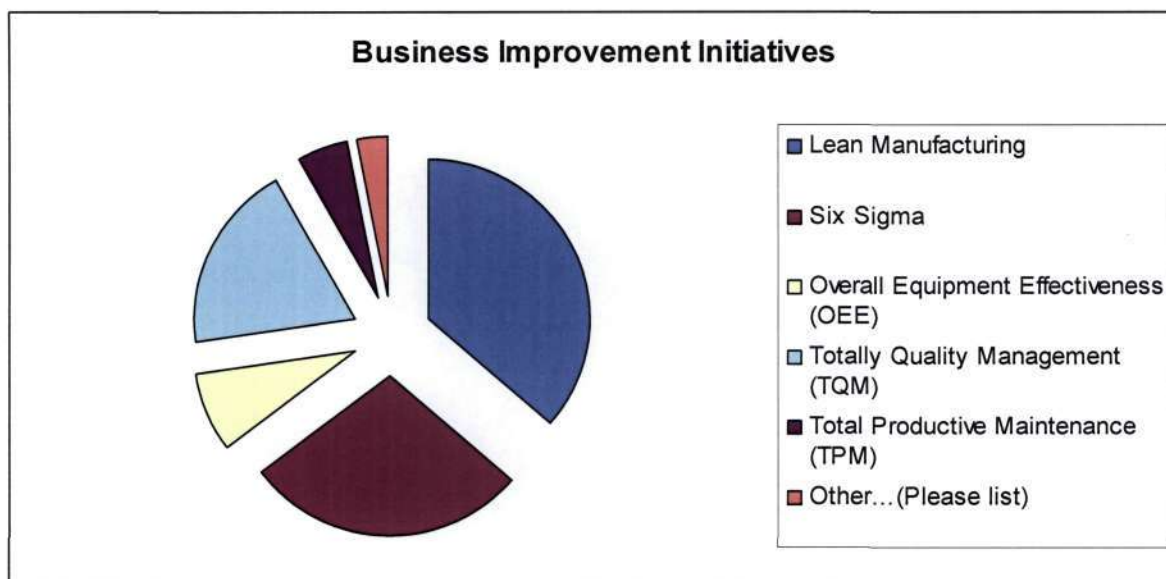


Figure 4.5: Analysis of research questionnaire responses by business improvement initiatives.

Introduction to Figure 4.5: This is a pie graph which depicts the breakdown the analysis of the responses to the research questionnaire by business improvement initiatives used in organisations.

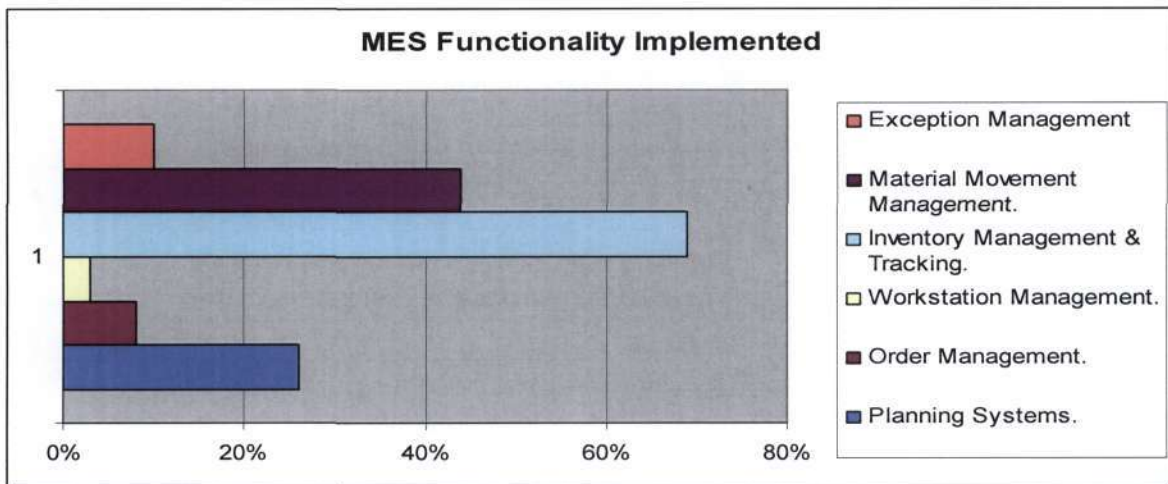
Lean Manufacturing which has its origins in the Toyota Motor Corporation plants in Japan. Its inventor Taiichi Ohno started the basics of Lean after a visit to the General Motors plant in the United States. Lean manufacturing is prevalent in 59% of organisations (Ohno, 1988). Six Sigma which has its origins in General Electric Corporation under Jack Welch is present in 46% of respondents companies. The Six Sigma methodology revolves around the DMAIC principle which translates into Design, Measure, Analyse, Improve and Control (Gack, 2006). Overall Equipment Effectiveness (OEE) seemed to be very popular in the Metals, Mining, and Minerals Industry verticals and is present in 13% of the respondents' organisations. OEE looks at the overall effectiveness of each machine in production line and measures the overall uptime of each of the machines in the line as well as the production and quality levels of each machine. OEE strives to get to a point where all machines in a production line run at their nameplate ratings (Pieterse, 2005).

Total Quality Management (TQM) also has its roots in Japan in the automotive industry and aims to get a production facility to maintain a certain level of quality throughout a shift or day. TQM is present in 31% of respondent's organisations (Liker, 2004).

Total Productive Maintenance (TPM) is another Japanese invention and aims to maintain a high OEE by having a maintenance schedule that will provide the maximum uptime for a plant with minimum unplanned stoppages due to machine failures or breakdowns. TPM is present in 8% of respondent's organisations (Liker, 2004).

"Other" which represents 3% is mainly made up of in-house initiative which focuses on specific areas of the business like an initiative to reduce paper usage in an organisation.

#### 4.2.6 MES functionality implemented



**Figure 4.6: Analysis of research questionnaire responses by MES functionality implemented.**

Introduction to Figure 4.6: This is a horizontal bar graph which depicts the breakdown of the analysis of the responses to the research questionnaire by MES functionality that these organisations had implemented or were busy implementing.

This graph shows the major MES functionalities that organisations have implemented or were busy implementing. The Exception Management function, which is implemented in 10% of respondents' organisations, provides the ability to respond to unanticipated events that affect the production plan, such as a bill-of-materials item shortage for a work order in process. (McClellan, 2004).

The Material Movement Management functionality, which is implemented in 44% of respondents' organisations, is either manual or automated; organizations schedule and manage the movement of material through this function. (McClellan, 2004).

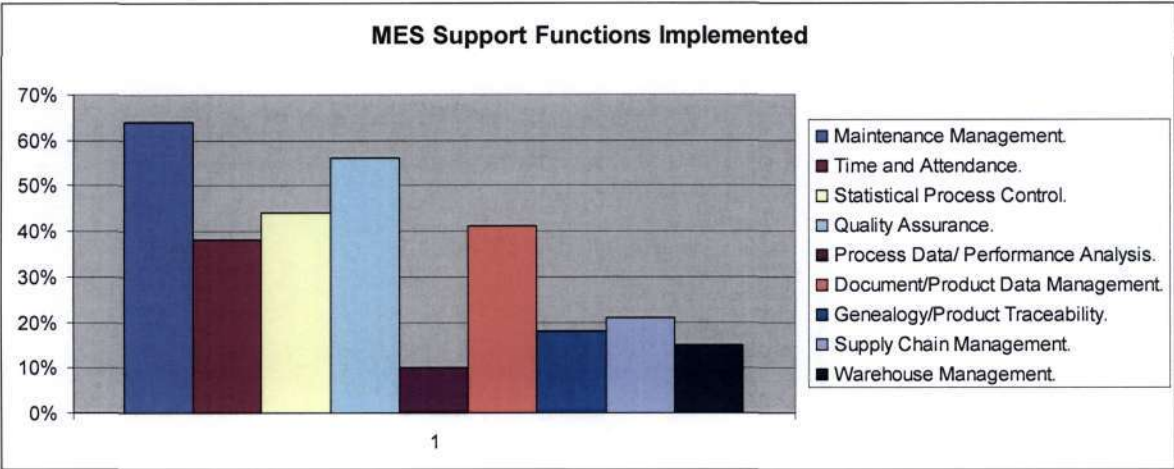
An Inventory Tracking and Management function develops, stores, and maintains the details of each batch, lot, or unit of inventory of the work-in-process (McClellan, 2004). This function is most popular and implemented in 64% of respondents' organisations.

The Workstation Management function is responsible for implementing the works order production plan, workstation scheduling, and the logical configuration of each workstation. (McClellan, 2004). This function is implemented in 3% of respondents' organisations.

The Order Management functionality includes the accumulation and management of work orders that have been received from the ERP system. This function performs the following common tasks: making changes (such as quantity) to orders; combining or splitting orders; running short-term what-if analyses to determine best current resource use; and prioritizing and scheduling (McClellan, 2004). This function is implemented in 8% of respondents' organisations.

The Planning System functionality is the connection with the planning system (ERP) and defines how and what information is exchanged (McClellan, 2004). This function is implemented in 26% of respondents' organisations.

**4.2.7 MES support functionality implemented**



**Figure 4.7: Analysis of research questionnaire responses by MES support functionality implemented.**

Introduction to Figure 4.7: This is a vertical bar graph which depicts the breakdown of the responses to the research questionnaire by MES support functionality that these organisations had implemented or were busy implementing.

This graph shows the MES support functionality that organisations have implemented or were implementing. From the graph it is clear that Maintenance Management, sometimes called "asset" management, is the most popular support function among the respondents. Maintenance Management is the function that manages production equipment maintenance-

related issues, including predictive maintenance, work order and labour scheduling, procurement and storage of the repair parts inventory, and equipment-record maintenance (McClellan, 2004). This support functionality is implemented in 64% of respondents' organisations.

The Time and Attendance Systems usually includes clock-in/clock-out information along with labour data collection and employee skills data (McClellan, 2004). This support functionality is implemented in 38% of respondents' organisations.

Statistical Process Control (SPC). This quality control method focuses on continuous process monitoring rather than the inspection of finished products (McClellan, 2004). This support functionality is implemented in 44% of respondents' organisations.

Quality Assurance packages may or may not be tied together with SPC and/or ISO 9000 systems. Separate or combined, quality assurance packages are frequent components of the production process (McClellan, 2004). This support functionality is implemented in 56% of respondents' organisations.

Process Data/Performance Analysis manages process data collection and management. It can be a standard package developed for specific applications, such as time/cost variance information or manufacturing process records (McClellan, 2004). This support functionality is implemented in 10% of respondents' organisations.

The Document/Product Data Management can be a very large component of the manufacturing system used to create product drawings and process information and then supply that data for plant-floor use (McClellan, 2004). This support functionality is implemented in 41% of respondents' organisations.

Genealogy/Product Traceability are similar functions designed to provide a complete history of a serialized item or a group of items. In addition to the locally generated production data, most systems can include similar information on each bill-of-materials item going into the finished product (McClellan, 2004). This support functionality is implemented in 18% of respondents' organisations.

Supply Chain Management enables suppliers to be connected to supply a wide range of information. Data may include information about genealogy, schedule, quality assurance, and logistics (McClellan, 2004). This support functionality is implemented in 21% of respondents' organisations.

Warehouse Management systems are primarily for monitoring and managing outbound inventory activities, with some systems also capable of inbound raw or purchased material management (McClellan, 2004). This support functionality is implemented in 15% of respondents' organisations.

**4.3 The MES Decision Process**

The following questions were aimed at the decision making process in the respondents' organisations and how the organisations arrived at the decision.

**4.3.1 Key Drivers for Implementing an MES Solution.**

**4.3.1.1 Mapping customer orders to specific production runs**



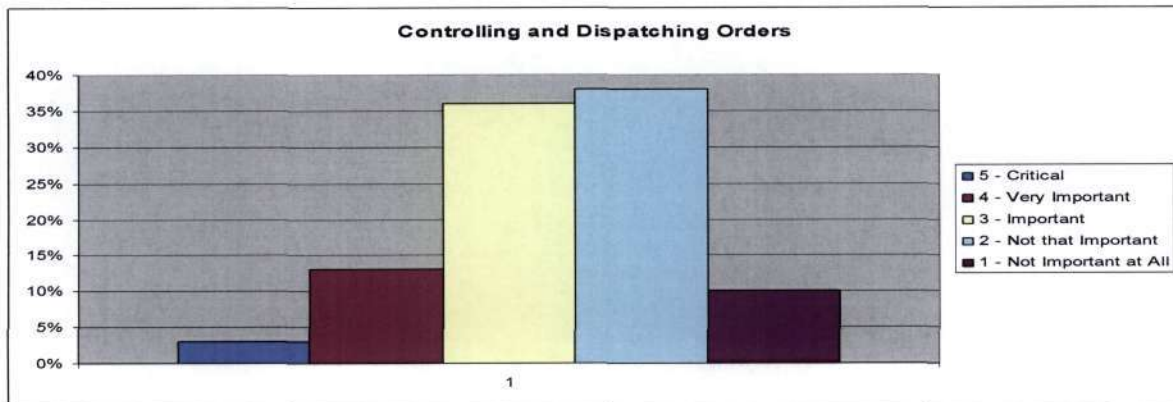
**Figure 4.8: Mapping customer orders to specific production runs.**

Introduction to Figure 4.8: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, mapping customer orders to specific production runs, to the respondents.

The responses to the question on the importance of this business driver in the MES decision process were as follows, Not important at all – 28%, Not that important – 41%, Important –

23%, Very important – 8% and critical – 0%. This driver is found to be not that important in the MES decision by most of the organisations that responded.

#### 4.3.1.2 Controlling and dispatching orders

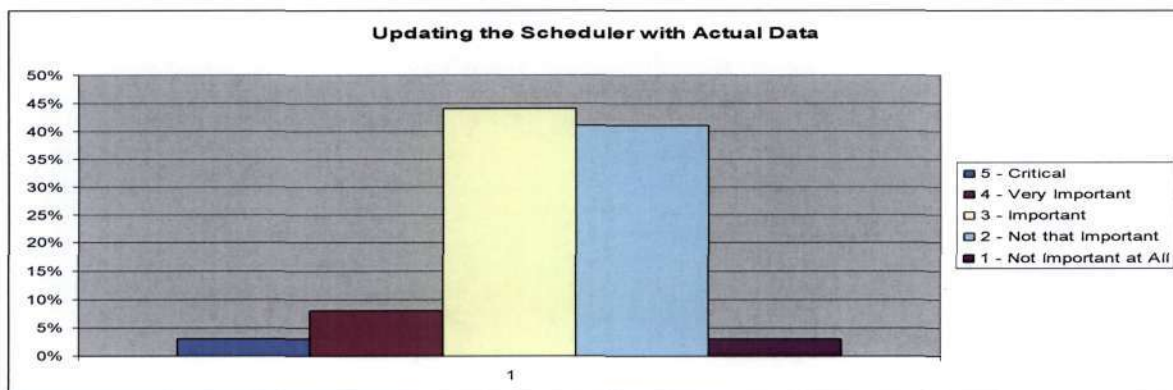


**Figure 4.9: Controlling and dispatching orders**

Introduction to Figure 4.9: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, controlling and dispatching orders, to the respondents.

The responses to the question on the importance of this business driver in the MES decision process was as follows, Not important at all – 10%, Not that important – 38%, Important – 36%, Very important – 13% and Critical – 3%. This driver is found to be somewhat important, in the MES decision by most of the organisations that responded.

#### 4.3.1.3 Updating the scheduler with actual data (e.g., labour, material and machines)



**Figure 4.10: Updating the scheduler with actual data.**

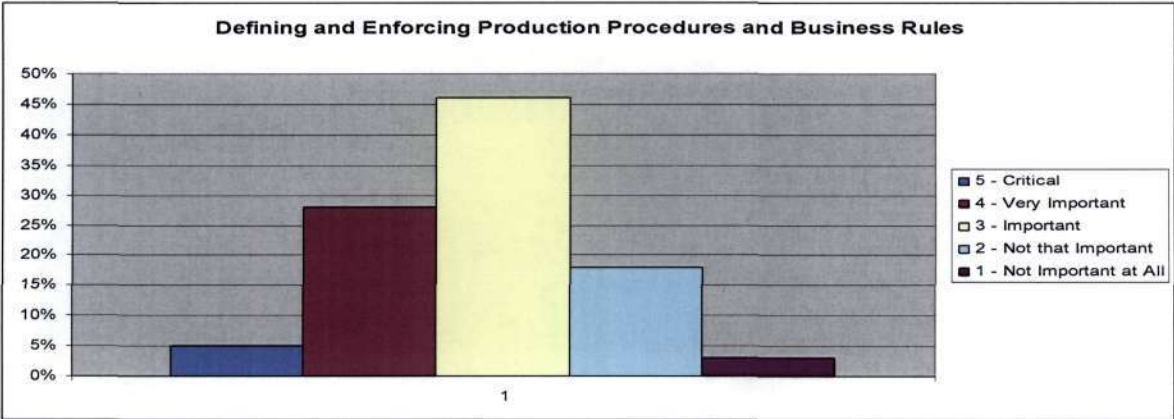
Introduction to Figure 4.10: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, updating the scheduler with actual data, to the respondents.

In the graph the responses to the question on the importance of this business driver in the MES decision process was as follows, Not important at all – 3%, Not that important – 41%, Important – 44%, Very important – 8% and Critical – 3%. This driver is found to be somewhat important, in the MES decision by most of the organisations that responded.

**4.3.1.4 Defining and enforcing production procedures and business rules.**

Introduction to Figure 4.11: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, defining and enforcing production procedures and business rules, to the respondents.

This graph shows that the responses to the question on the importance of this business driver in the MES decision process were, Not important at all – 3%, Not that important – 18%, Important – 46%, Very important – 28% and Critical – 5%. This driver is found to be important in the MES decision by most of the organisations that responded.



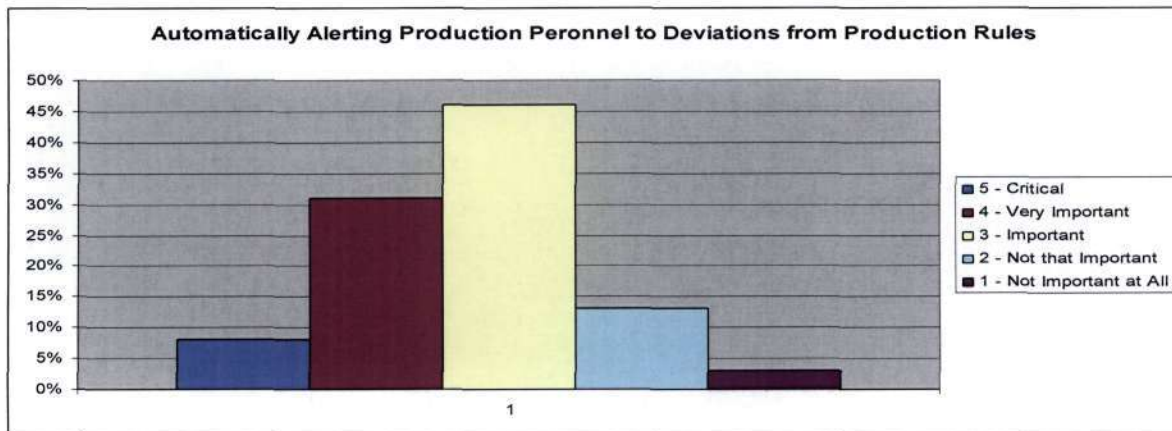
**Figure 4.11: Defining and enforcing production procedures and business.**



Introduction to Figure 4.11: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, defining and enforcing production procedures and business rules as a key driver for implementing a MES solution.

The responses to the question on the importance of this business driver in the MES decision process, as can be seen in the graph above, was as follows, Not important at all – 3%, Not that important – 18%, Important – 46%, Very important – 28% and Critical – 5%. This driver is found to be important in the MES decision by most of the organisations that responded.

**4.3.1.5 Automatically alerting production personnel to deviations from production rules.**

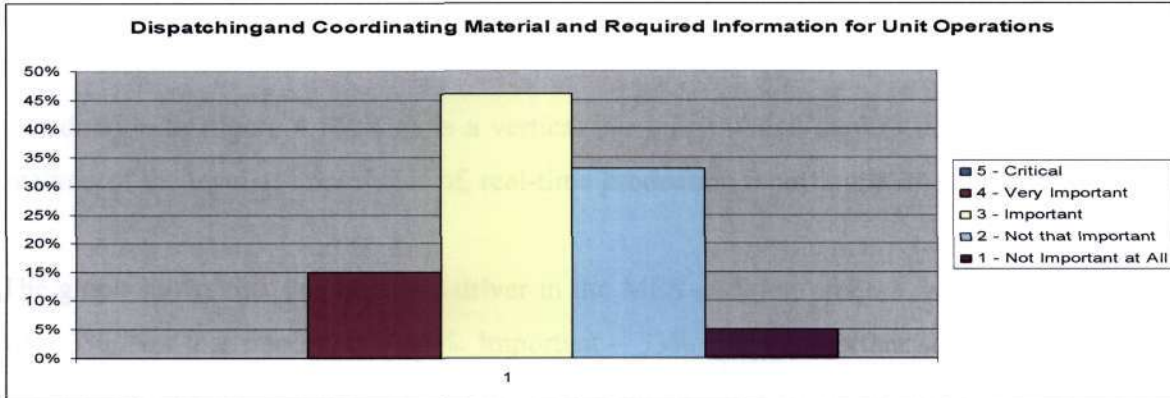


**Figure 4.12: Automatically alerting production personnel to deviations from production rules.**

Introduction to Figure 4.12: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, automatically alerting production personnel to deviations from production rules, to the respondents.

The responses to the question on the importance of this business driver in the MES decision process was as follows, Not important at all – 3%, Not that important – 13%, Important – 46%, Very important – 31% and Critical – 8%. This driver is found to be important in the MES decision by most of the organisations that responded.

#### 4.3.1.6 Dispatching and coordinating material and required information for unit operations.

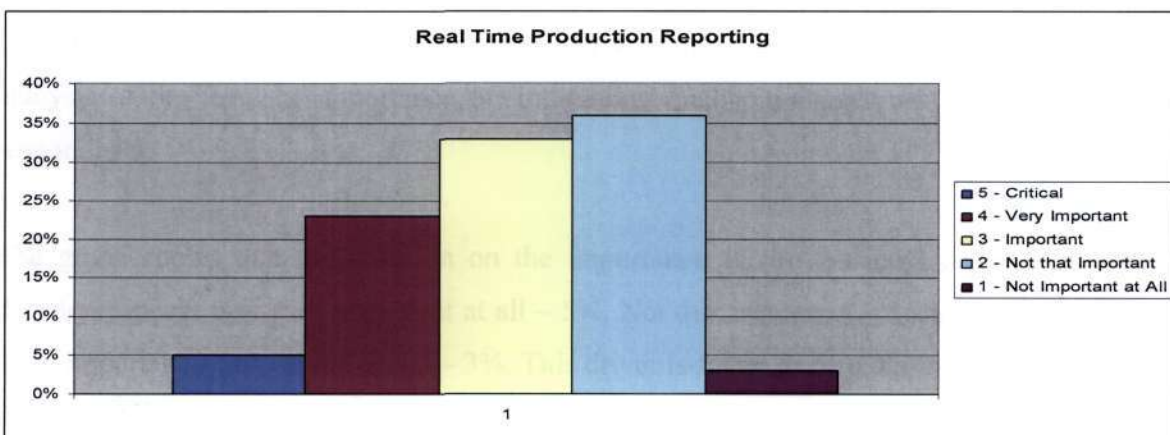


**Figure 4.13: Dispatching and coordinating material and required information for unit operations.**

Introduction to Figure 4.13: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, dispatching and coordinating material and required information for unit operations, to the respondents.

The responses to the question on the importance of this business driver in the MES decision process was as follows, Not important at all – 5%, Not that important – 33%, Important – 46%, Very important – 15% and Critical – 0%. This driver is found to be important in the MES decision by most of the organisations that responded.

#### 4.3.1.7 Real-time production reporting (e.g., materials usage and scrap).

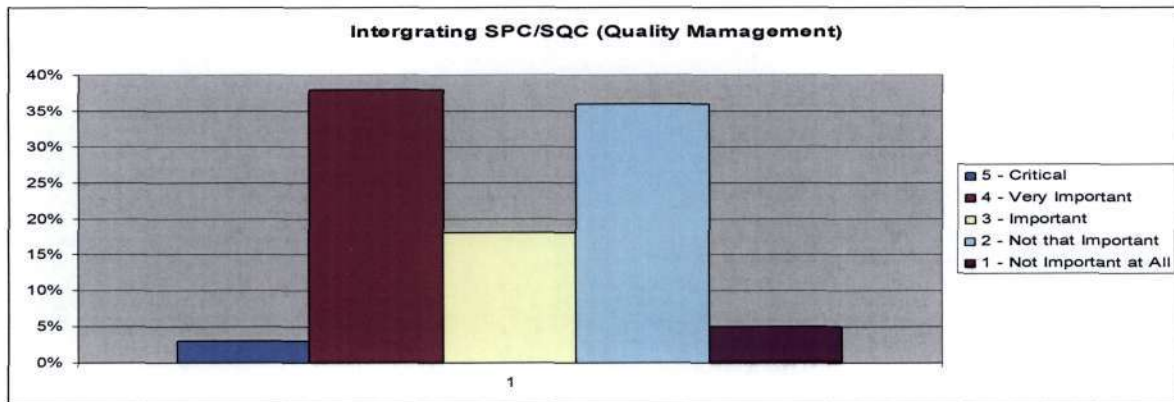


**Figure 4.14: Real time production reporting.**

Introduction to Figure 4.14: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, real-time production reporting, to the respondents.

The graph shows that this business driver in the MES decision process was, Not important at all – 3%, Not that important – 36%, Important – 33%, Very important – 23% and Critical – 5%. This driver is found to be between, not that important and important with very important featuring strongly in the MES decision by most of the organisations that responded.

#### 4.3.1.8 Integrating Quality Management.

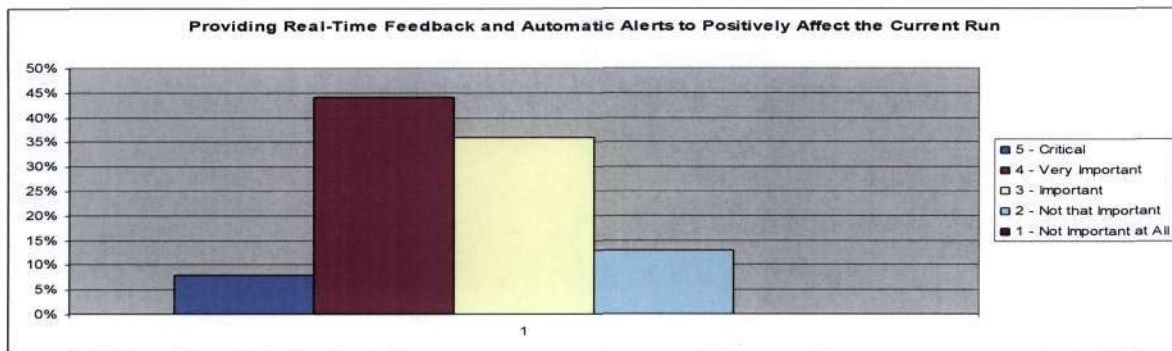


**Figure 4.15: Integrating quality management information.**

Introduction to Figure 4.15: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, integrating quality management information, to the respondents.

The graph shows that the question on the importance of this business driver in the MES decision process was, Not important at all – 5%, Not that important – 36%, Important – 18%, Very important – 38% and Critical – 3%. This driver is found to be either not that important to companies in mining and water & wastewater vertical industries and very important to companies the pharmaceutical and food & beverage vertical industries. This driver seems to be industry specific.

#### 4.3.1.9 Providing real-time feedback and automatic alerts to positively affect the run.

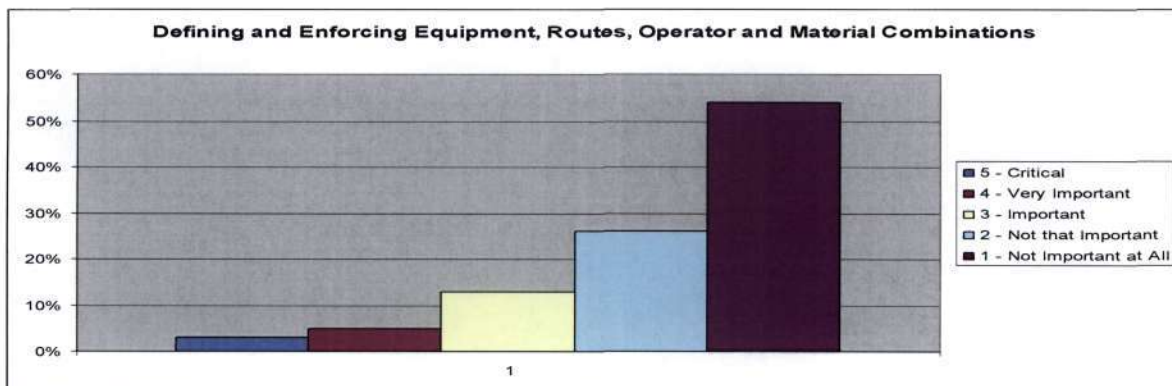


**Figure 4.16: Providing real-time feedback and automatic alerts to positively affect the current run.**

Introduction to Figure 4.16: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, providing real-time feedback and automatic alerts to positively affect the run, to the respondents.

The responses to the question on the importance of this business driver in the MES decision process was as follows, Not important at all – 0%, Not that important – 13%, Important – 36%, Very important – 44% and Critical – 8%. This driver is found to be important in the MES decision by most of the organisations that responded.

#### 4.3.1.10 Defining and enforcing specific equipment, routes, operator and material combinations.

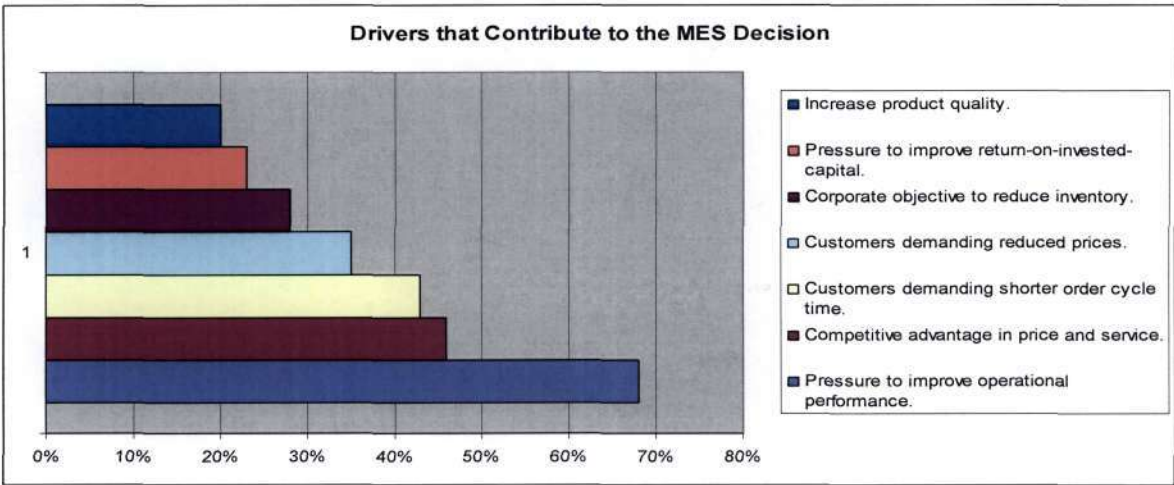


**Figure 4.17: Defining and enforcing equipment, routes, operator and material combinations.**

Introduction to Figure 4.17: This is a vertical bar graph which depicts the breakdown of the analysis of the level of importance of, defining and enforcing specific equipment, routes, operator and material combinations, to the respondents.

In figure 4.17 the responses to the question on the importance of this business driver in the MES decision process was as follows, Not important at all – 54%, Not that important – 26%, Important – 13%, Very important – 5% and Critical – 3%. This driver is found to be not important at all in the MES decision by most of the organisations that responded.

**4.3.2 Business Drivers that contribute to the MES decision**

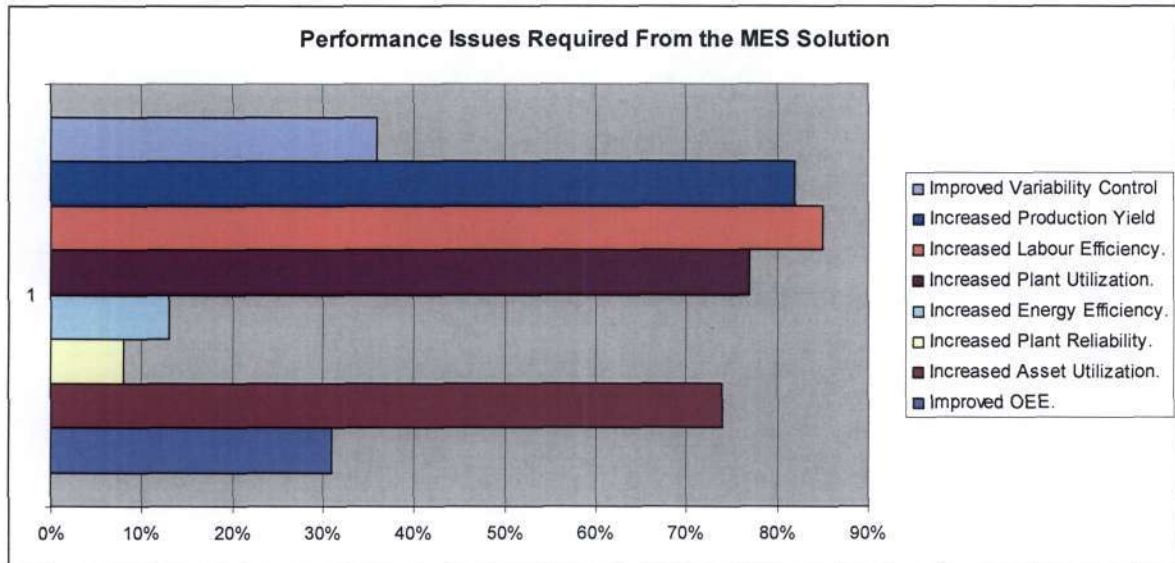


**Figure 4.18: Analysis of the drivers that contribute to the MES decisions.**

Introduction to Figure 4.18: This is a horizontal bar graph which depicts the breakdown of the analysis of the demands that are placed on organisations in today’s modern world either by shareholders or outside competitive pressures.

In the above figure 4.18 the pressure to improve operational performance is rated by 68% of organisations as a demand that is placed on them and was a driver that played the largest part in the MES decision. This is followed by competitive advantage in price and service at 46%, customers demanding shorter order cycle time at 43%, customers demanding reduced prices at 35%, corporate objective to reduce inventory at 28%, pressure to improve return-on-invested-capital at 23% and finally increase product quality at 20 %

### 4.3.3 Performance issues required from the MES solution



**Figure 4.19: Performance issues required from the MES solution.**

Introduction to Figure 4.19: This is a horizontal bar graph which depicts the breakdown of the analysis of the areas of performance improvement required from the MES solution by the organisations.

As figure 4.19 shows improved OEE was a requirement of 31% of the responding organisations. Increased Asset Utilization was required by 74% of the organisations. Increased Plant Reliability was a requirement of 8% of the organisations. Increased Energy Efficiency was a requirement of 13% of the organisations. Increased Plant Utilization was a requirement of 77% of the organisations. Increased Labour Efficiency was a requirement of 85% of the organisations. Increased Production Yield was a requirement of 82% of the organisations. Improved Variability Control was a requirement of 36% of the organisations.

### 4.3.4 Level of involvement of stakeholder in the MES decision

Introduction to Figure 4.20: This is a horizontal bar graph which depicts the breakdown of the analysis of the average involvement of the organisations' stakeholders in the MES decision process.

In the figure 4.20 the level to which this decision is escalated in these organisations is clear. The Plant Operators are involved in the MES decision process while the Plant Manager is very involved. The Control & Instrumentation Department are permanently involved and the Engineering Department is only involved. The IT Department is involved while the Engineering Director/Manager is permanently involved. The Operations Director/Manager is very involved while the IT Director/Manager is only involved. The Financial Director/Manager is involved while the Board members, the CEO / Managing Director and the President of the company are not involved at all.

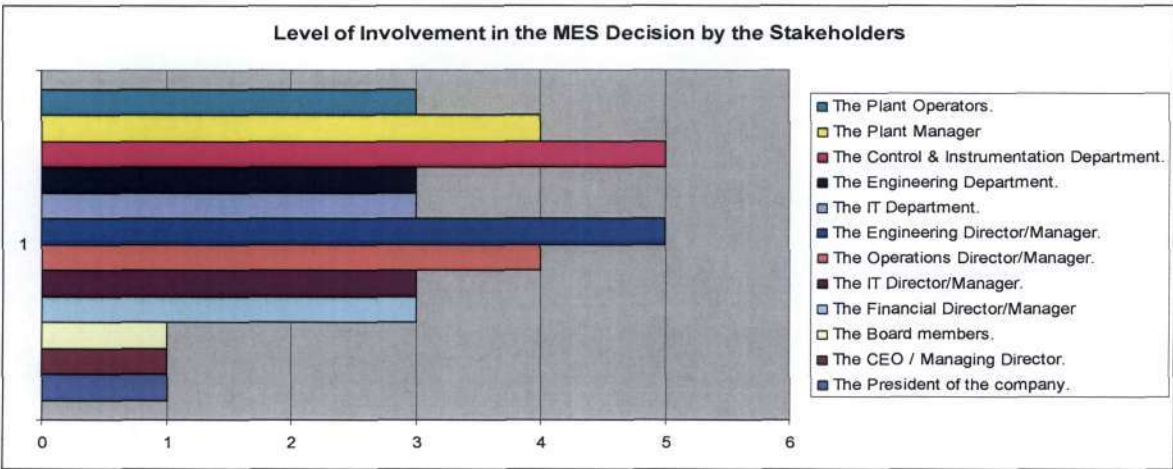


Figure 4.20: Analysis of the level of involvement in the MES decision by the stakeholder.

4.3.5 Timeframe of the MES decision

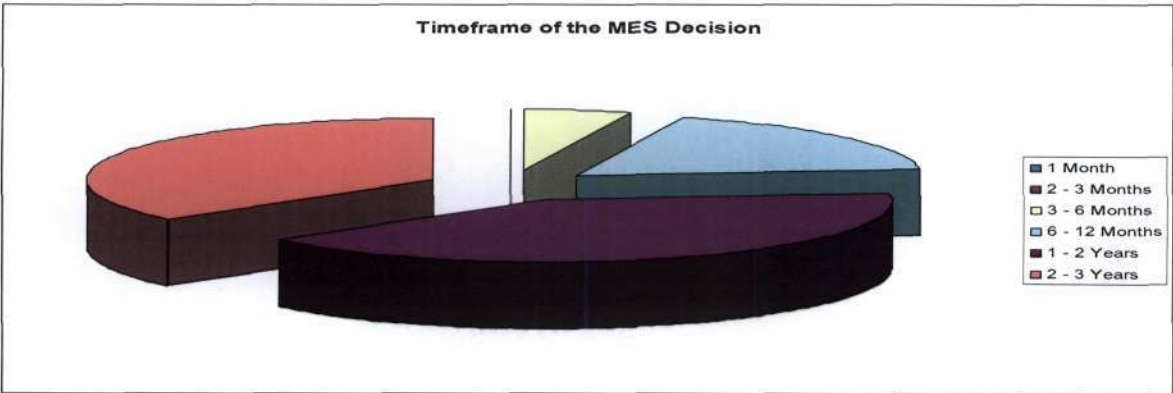
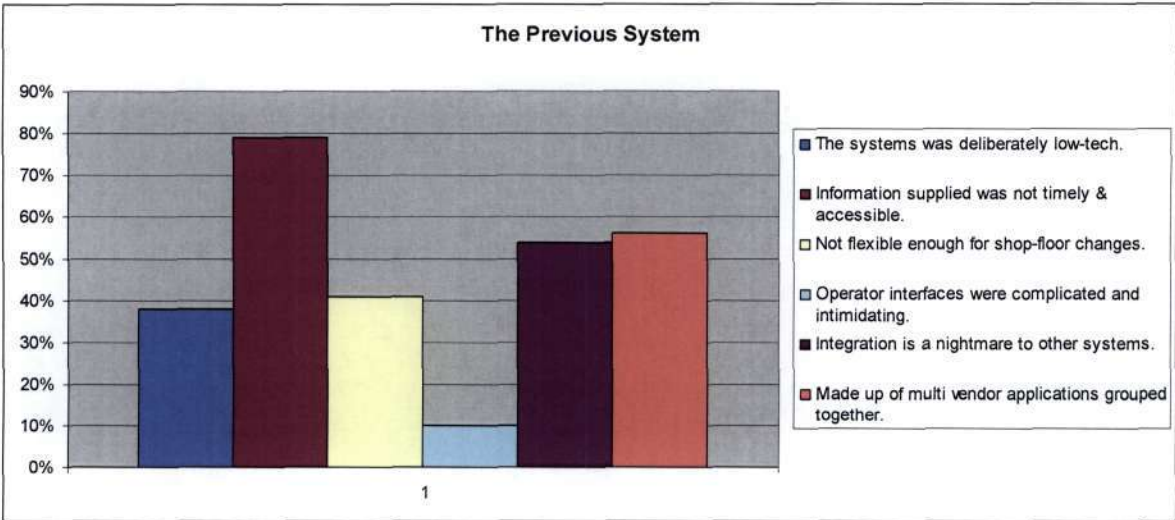


Figure 4.21: Timeframe of the MES decision.

Introduction to Figure 4.21: This is a pie graph which depicts the breakdown of the analysis of the timeframe of the MES decision from the date that a MES solution is first tabled to the date when the contract and project plans are signed.

In this graph none of the organisations that responded made their MES decision within a three month period and only 5% had made their decision within the three to six month period. In the period six to twelve months 18% of organisations had made their decision. In the one to two year bracket the largest group can be found with 41% of organisations finalising their decision in this time frame. The final group of 36% of organisations reached their decision in two to three years. There seems to be a correlation between the time taken to reach a decision and the level of management involved. There is a suspicion that the higher the level management involved the longer the timeframe to reach a decision and the better chance of success the implementation project has (see figure 4.3.3 & 4).

**4.3.6 The system that was to be replaced by the MES solution**



**Figure 4.22: Shortcomings of the previous system.**

Introduction to Figure 4.22: This is a vertical bar graph which depicts the breakdown of the analysis of the major limitations of the previous, MES system or system to be replaced.

The fact that the system was deliberately low-tech was a concern for 38% of the organisations while the fact that information supplied was not timely and accessible was a concern for 79%



of organisations. The fact that the system was not flexible enough for shop-floor changes was a concern for 41% of organisations. The fact that the operator interfaces were complicated and intimidating was a concern for only 10% of organisations. The fact that integration between other systems was very problematic was a concern for 54% of organisations and the fact that the system was made up of multi vendor applications grouped together was a concern for 56% of organisations.

### 4.4 Implementation Strategy and Methodology

#### 4.4.1 The importance of internal IT decisions in the organisation.

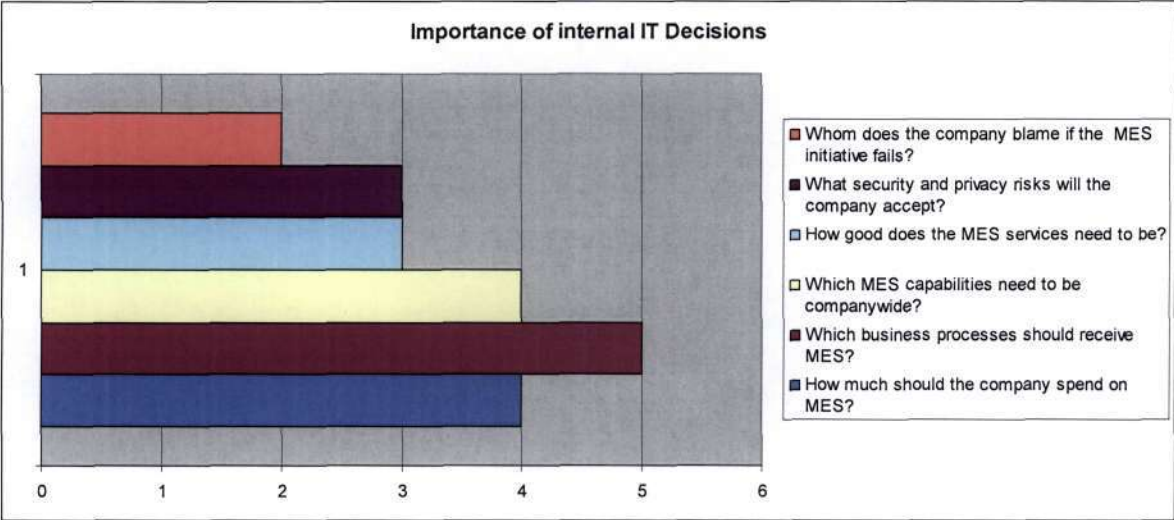


Figure 4.23: Analysis of the importance of internal IT decisions.

Introduction to Figure 4.23: This is a horizontal bar graph which depicts the breakdown of the analysis of the importance of certain internal IT decisions to the organisations.

The person or group who makes the decision will place the highest priority on the areas that affect them directly. The organisations that responded to this questionnaire felt that finding somebody to blame (somebody to take responsibility for the initiative) if the MES initiative fails is not that important. Security and privacy risks decisions are rated as important and also the question on how good the MES service needs to be. Decisions regarding which capabilities need to be companywide and how much should the company should spend on MES are rated

as very important while only the decision about which business processes should receive MES is perceived to be critical.

#### 4.4.2 Which contractual considerations are important

Introduction to Figure 4.24: This is a vertical bar graph depicts the breakdown of the analysis of the importance of contractual considerations in the organisations.

It is clear from the figure 4.24 below that contractual considerations are a high priority in the organisations that responded. Collaboration between the MES software vendor and the company and clear and open communication between the MES software vendor and the company were rated as critical to these organisations. Negotiations of payment terms with the MES vendor and defining the service levels that must be met for the implementation to be complete only rated as important while including the “professional services” piece in the MES contract was rated as very important by the organisations that responded to the question.

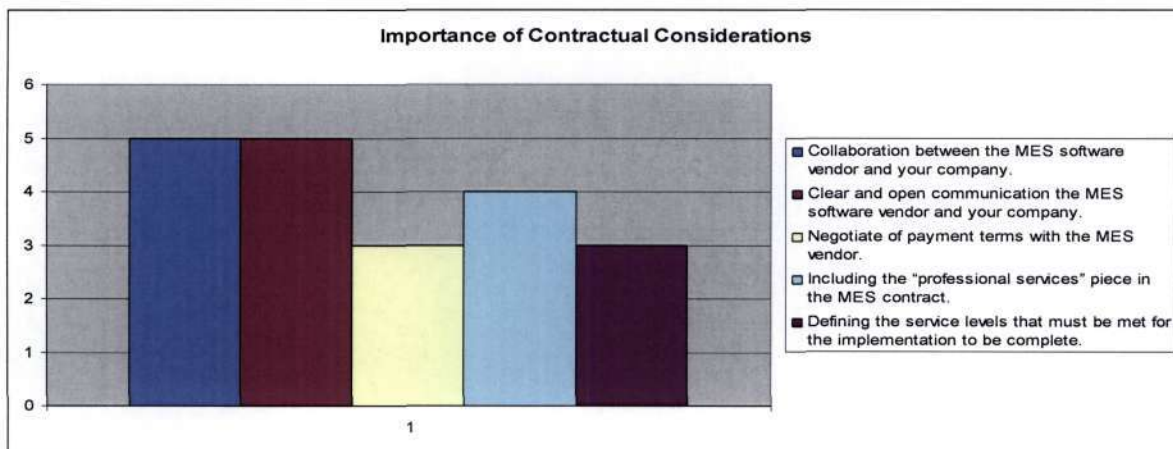
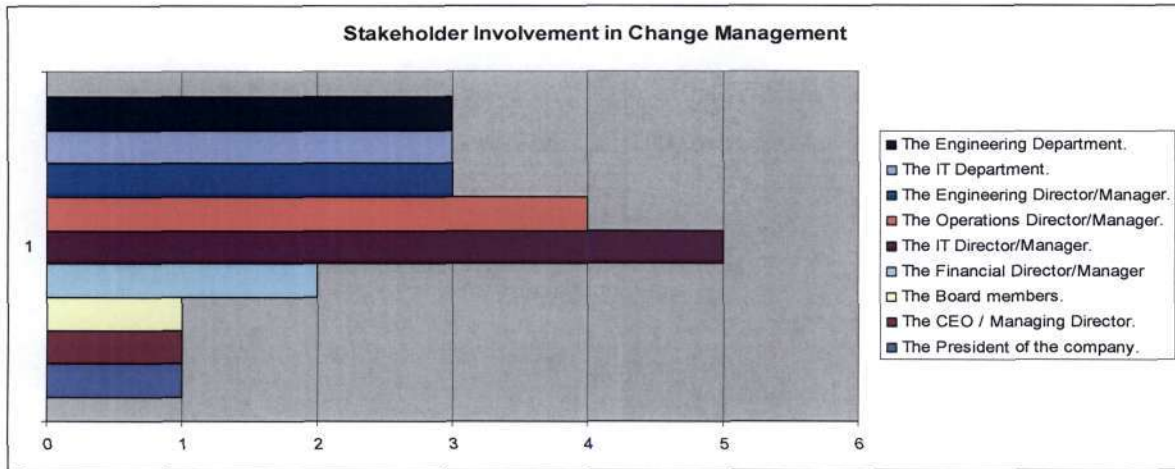


Figure 4.24: Analysis of the importance of contractual considerations.

### 4.4.3 Involvement of stakeholders in implementing change management.

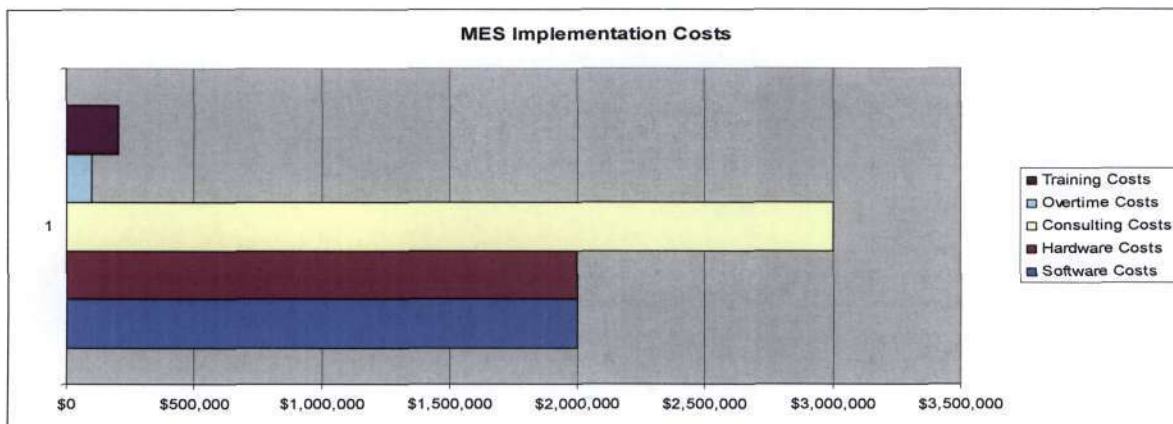


**Figure 4.25: Analysis of the stakeholder involvement in the change management of the organisation.**

Introduction to Figure 4.25: This is a horizontal bar graph which depicts the breakdown of the analysis of stakeholder involvement in implementing change management in the organisation.

Change management is all the activities involved in getting the users of the MES solution to buy into the idea of a new MES solution and realise that the new MES solution is for the benefit of everybody in the organisation. In the organisations that responded the Engineering Department, the IT Department and the Engineering Director/Manager were all seen to be involved. The Operations Director/Manager was seen to be very involved while the IT Director/Manager was seen to be permanently involved. The Financial Director/Manager had a small involvement while the Board members, the CEO / Managing Director and the President of the company had no involvement at all. In many plants the head office where the CEO, President and Board Member have offices is often far away from the plants or mines (also see Figure 4.3.5).

#### 4.4.4 Approximate spend on the MES implementation

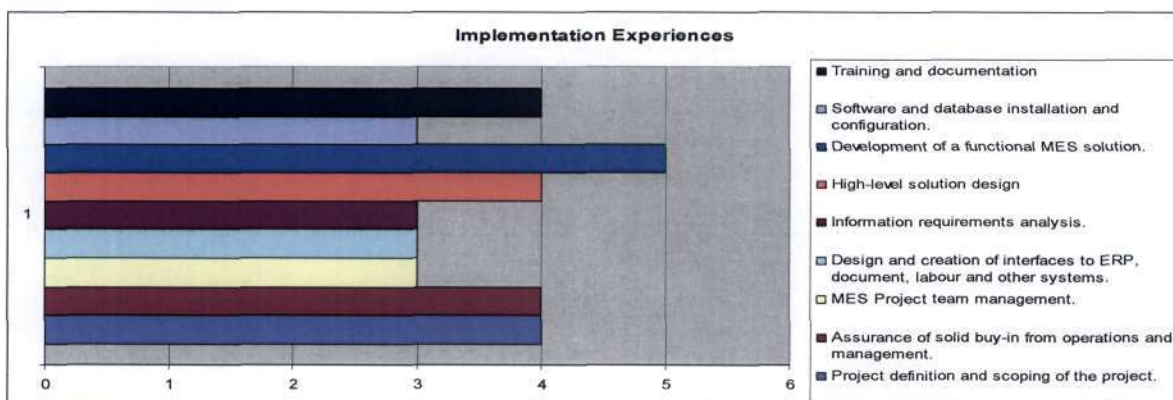


**Figure 4.26: Analysis of the costs involved in a MES implementation.**

Introduction to Figure 4.26: This is a horizontal bar graph which depicts the breakdown of the analysis of MES implementation spent on each of the following categories of the MES implementation.

From the figure 4.26 the cost for training amounts to only 1% of total implementation costs. Staff overtime costs amounted to only 2% of total implementation cost. Consulting or Consultancy costs amounted to 41% of total implementation costs and hardware and software costs each amounted to 27% of total implementation costs. It is not surprising that the current size of the MES market is estimated at \$2 billion and that only 1% of this is spent on equipping the people who will operate the system with the right skills.

#### 4.4.5 Implementation experiences with different stages of the implementation



**Figure 4.27: Implementation experiences of organisations.**

Introduction to Figure 4.27: This is a horizontal bar graph which depicts the breakdown of the analysis of the rating by organisations of the level of difficulty of a list of the steps of a typical MES implementation process.

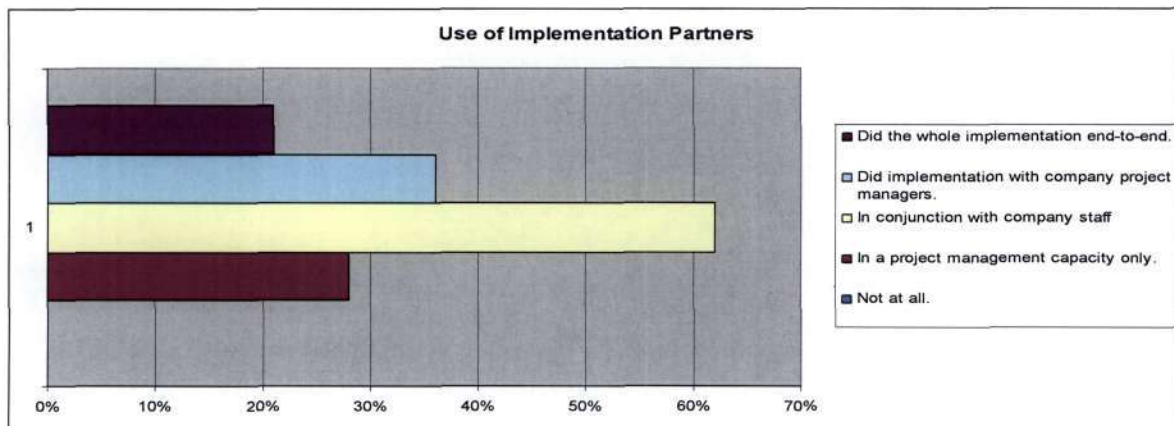
Project definition and scoping of the project.	4	Very Difficult
Assurance of solid buy-in from operations and management.	5	Very Difficult
MES Project team management.	3	Not too Difficult
Design and creation of interfaces to ERP, document, labour and other systems.	3	Not too Difficult
Information requirements analysis.	3	Not too Difficult
High-level solution design	4	Very Difficult
Development of a functional MES solution.	4	Extremely Difficult
Software and database installation and configuration.	3	Not too Difficult
Training and documentation	4	Very Difficult

**Table 4.27: Implementation experiences of organisations.**

Introduction to Table 4.27: This is a horizontal table which depicts the breakdown of the analysis of the rating by organisations of the level of difficulty of a list of the steps of a typical MES implementation process.

In Figure 4.27 and summarised in table4.27 the project definition and scoping of the project as well as the assurance of solid buy-in from operations and management are two steps that were rated very difficult by the respondents. The MES Project team management, design and creation of interfaces to ERP, document, labour and other systems and the information requirements analysis are all steps that were rated as not too difficult. The high-level solution design was rated as very difficult while the development of a functional MES solution was rated as extremely difficult. The software and database installation and configuration was rated as not too difficult while training and documentation was rated very difficult.

#### 4.4.6 Implementation Partners



**Figure 4.28: Organisations use of implementation partners.**

Introduction to Figure 4.28: This is a horizontal bar graph which depicts the breakdown of the analysis of the extent to which implementation partners are used by organisations.

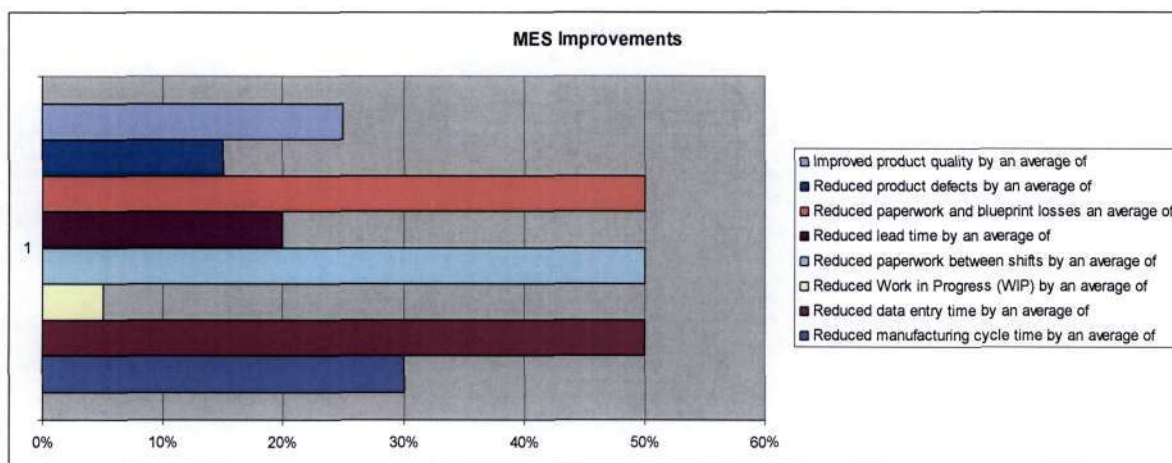
Implementation partners are outside companies that are often associated with the MES vendor and are skilled in the implementation of MES solutions. Of the respondents 0% did not use implementation partners at all. The respondents who used partners in a project management capacity only were 28% and 62% used them in conjunction with their own staff. 36 % of respondents did the implementation with company project managers and 21% let the implementation partners do and maintain the solution end to end.

#### 4.4.7 MES implementation improvements

Introduction to Figure 4.29: This is a Horizontal bar graph which depicts the breakdown of the analysis of the average percentage improvements that responding companies have experienced since implementing the MES solution.

The Graph below indicates that MES reduced manufacturing cycle time by an average of 30%, reduced data entry time by an average of 50%, and reduced Work in Progress (WIP) by an average of 5%. MES reduced paperwork between shifts by an average of 50%, reduced lead time by an average of 20% MES reduced paperwork and blueprint losses an average of 50%,

reduced product defects by an average of 15% and improved product quality by an average of 25%.



**Figure 4.29: Improvements experienced after implementing a MES solution.**

## 4.5 Statistical Analysis

All the data collected from the returned research questionnaires were input into the SPSS software and the results were tabled in Microsoft Excel to create the graphs.

### 4.5.1 Chi-Square Goodness-of-Fit Test.

The chi-square test is used to test if a sample of data came from a population with a specific distribution. An attractive feature of the chi-square test is that it can be applied to any unvaried distribution for which you can calculate the cumulative distribution Function. The chi-square goodness-of-fit test is applied to binned data i.e., data put into classes (Snedecor and Cochran, 1989).

Chi-square goodness-of-fit tests were carried out on the responses to the following questions of the research questionnaire. The aim was to see if significantly more respondents chose a certain rating more or less often than expected.

**Question 6: Please rate the following key drivers for implementing a MES solution by your company?**

The ratings were as follows:

1. Not important at all.
2. Not that important.
3. Important.
4. Very Important.
5. Critical

The hypothesis tested for each of these questions/key drivers is: There is an equal chance of them getting a 1, 2, 3, 4 or 5 rating and each of these questions came out significant.

Mapping customer orders to specific production runs.	Not that important
Controlling and dispatching orders.	Not that important
Updating the scheduler with actuals (e.g., labour, material and machines).	Not that important/Important
Defining and enforcing production procedures and business rules.	Important
Automatically alerting production personnel to deviations from production rules.	Important
Dispatching and coordinating material and required information for unit operations.	Important
Real-time production reporting (e.g., materials usage and scrap).	Not that important/Important
Integrating SPC/SQC (quality management).	Very important
Providing real-time feedback and automatic alerts to positively affect the current run.	Very important
Defining and enforcing specific equipment, routes, operator and material combinations.	Not important at all

**Table 4.5.1: Analysis of the choices of the respondents to Question 6.**

Introduction to Table 4.5.1: This table contains the responses to the answers to Question 6 of the research questionnaire.

Interpretation of results in Table 4.5.1: More than expected (frequency higher than 5) of the respondents chose the above ratings for these options as can be seen in the table 4.5.1a below which shows the actual chi-square ratings that each of the parts of the questions achieved.



Test Statistics

	Mapping customer orders to specific production runs	Controlling and dispatching orders	Updating the scheduler with actuals	Defining and enforcing production procedure	Automatically alerting production personnel to deviations from production rules	Dispatching and coordinating material and required info for unit ops	Real-time production reporting	Integrating SPC/SQC	Providing real time feedback and automatic alerts to positively affect the current run	Defining/enforcing specific equipment, routes, operator and material combinations
Chi-Square <sup>a,b,c</sup>	8.897	20.359	35.158	17.718	25.487	15.667	17.795	21.897	14.231	34.205
df	3	4	4	3	4	3	4	4	3	4
Asymp. Sig.	.031	.000	.000	.001	.000	.001	.001	.000	.003	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 9.8.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.8.

c. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.6.

**Table 4.5.1a: Chi-Square rating of the choices of the respondents to Question 6.**

**Question 12: Please rate the following internal IT decisions according to their importance as perceived in your organisation?**

The ratings were as follows:

1. Not important at all.
2. Not that important.
3. Important.
4. Very Important.
5. Critical

The hypothesis tested for each of these questions/key drivers is: There is an equal chance of them getting a 1, 2, 3, 4 or 5 rating and each of these questions came out significant.

How much should the company spend on MES?	Very important
Which business processes should receive MES?	Critical
Which MES capabilities need to be companywide?	Very important
How good does the MES services need to be?	Important
What security and privacy risks will the company accept?	Important
Whom does the company blame if the MES initiative fails?	Not important at all

**Table 4.5.2: Analysis of the choices of the respondents to Question 12.**

Introduction to Table 4.5.2: This table contains the responses to the answers to Question 6 of the research questionnaire.

Interpretation of results in Table 4.5.2: More than expected (frequency higher than 5) of the respondents chose the following rating for these options as can be seen in the table 4.5.2a below which shows the actual chi-square ratings that each of the parts of the questions achieved.

**Test Statistics**

	How much should the company spend on MES?	Which business processes should receive MES?	Which MES capabilities need to be companywide?	How good does the MES services need to be?	What security and privacy risks will the company accept?	Whom does the company blame if the MES initiative fails?
Chi-Square <sup>a, b, c</sup>	19.974	29.077	13.632	23.462	23.051	20.590
df	3	2	2	3	3	3
Asymp. Sig.	.000	.000	.001	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 9.8.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 13.0.

c. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 12.7.

**Table 4.5.1a: Chi-Square rating of the choices of the respondents to Question 12.**

**Question 13: Please rate the following internal IT decisions according to their importance as perceived in your organisation?**

1. The ratings were as follows:
2. Not important at all.
3. Not that important.
4. Important.
5. Very Important.
6. Critical

The hypothesis tested for each of these questions/key drivers is: There is an equal chance of them getting a 1, 2, 3, 4 or 5 rating and each of these questions came out significant.

Collaborative between the MES software vendor and your company.	Critical
Clear and open communication the MES software vendor and your company.	Critical
Negotiate of payment terms with the MES vendor.	Important
Including the “professional services” piece in the MES contract.	Very important
Defining the service levels that must be met for the implementation to be complete.	Important

**Table 4.5.3: Analysis of the choices of the respondents to Question 13.**

Introduction to Table 4.5.3: This table contains the responses to the answers to Question 6 of the research questionnaire.

Interpretation of results in Table 4.5.3: More than expected of the respondents chose the following rating for these options as can be seen in the table 4.5.3a below which shows the actual chi-square ratings that each of the parts of the questions achieved.

	Collaborative between the MES software vendor and your company.	Clear and open communication on the MES software vendor and your company.	Negotiate of payment terms with the MES vendor.	Including the "professional services" piece in the MES contract.	Defining the service levels that must be met for the implementation to be complete.
Chi-Square <sup>a,b</sup>	5.769	4.333	26.308	42.000	25.077
df	1	1	2	2	2
Asymp. Sig.	.016	.037	.000	.000	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 19.5.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 13.0.

**Table 4.5.3a: Chi-Square rating of the choices of the respondents to Question 13.**

**Question 16: What was your companies experience with each of the following challenges in the in the implementation of your MES solution?**

The ratings were as follows:

1. No Problem.
2. Not difficult at all.
3. Not too difficult.
4. Very difficult.
5. Extremely difficult.

The hypothesis tested for each of these questions/key drivers is: There is an equal chance of them getting a 1, 2, 3, 4 or 5 rating and not all of these questions came out significant as can be seen in the table below.

Project definition and scoping of the project.	Very difficult
Assurance of solid buy-in from operations and management.	Very difficult
MES Project team management.	Very difficult
Design and creation of interfaces to ERP, document, labour and other systems.	Not significant
Information requirements analysis.	Not significant

High-level solution design	Very difficult
Development of a functional MES solution.	Extremely difficult
Software and database installation and configuration.	Not too difficult
Training and documentation	Very difficult

**Table 4.5.4: Analysis of the choices of the respondents to Question 16.**

Introduction to Table 4.5.4: This table contains the responses to the answers to Question 6 of the research questionnaire.

Interpretation of results in Table 4.5.4: More than expected of the respondents chose the following rating for these options as can be seen in the table 4.5.4a below which shows the actual chi-square ratings that each of the parts of the questions achieved.

	Project definition and scoping of the project.	Assurance of solid buy-in from operations and management	MES Project team management.	Design and creation of interfaces to ERP, document, labour and other systems	Information requirements analysis.	High-level solution design	Development of a functional MES solution.	Software and database installation and configuration.	Training and documentation
Chi-Square <sup>a,b,c</sup>	27.846	17.077	10.744	7.282	7.795	17.513	14.641	12.462	28.308
df	2	2	3	4	4	3	3	2	4
Asymp. Sig.	.000	.000	.013	.122	.099	.001	.002	.002	.000

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 13.0.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 9.8.

c. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.8.

**Table 4.5.4a: Chi-Square rating of the choices of the respondents to Question 13.**

#### 4.5.2 Cross-tabulations and analysis

The following cross-tabs are of Question 2 of the research questionnaire cross-tabbed with the rest of the question. The reasoning behind this is that the hypothesis states that, MES implementations that are not thoroughly planned and properly specified and scoped before the implementation commences and is not driven from a very high level in the organisation will struggle to get a fully functional MES system implemented in the organisation.

Therefore the success of the implementation (question 2) needed to be measured against those questions that would provide answers that could be measured against the success of the implementations.



**Figure 4.30: Implementation success vs. mapping customer orders.**

Introduction to Figure 4.30: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the rating of the MES business driver by the responding organisations.

In Figure 4.30 it is clear that organisations that rated this specific MES business driver, mapping customer orders to specific production runs, as very important and important were far more successful in implementing their MES solutions than respondents that rated the driver not that important or not important at all. This phenomenon will have to be researched further to understand why this particular MES driver is linked to implementation success and no other drivers showed any relationship to the implementation success in the chi-square tests conducted (see appendix).

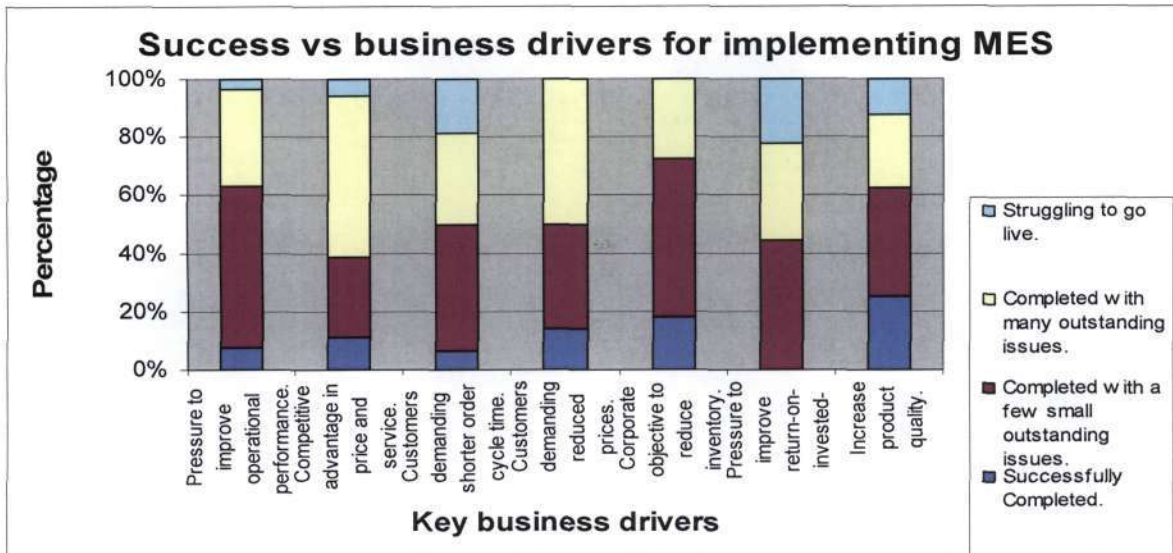


Figure 4.31: Implementation success vs. business drivers for implementing MES.

Introduction to Figure 4.31: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the business drivers that drive organisations to implement an MES solution.

In Figure 4.31 it seems that there is no significant relationship between implementation success and the business drivers for the implementation of MES solutions. This was also evident from the chi-square test conducted.

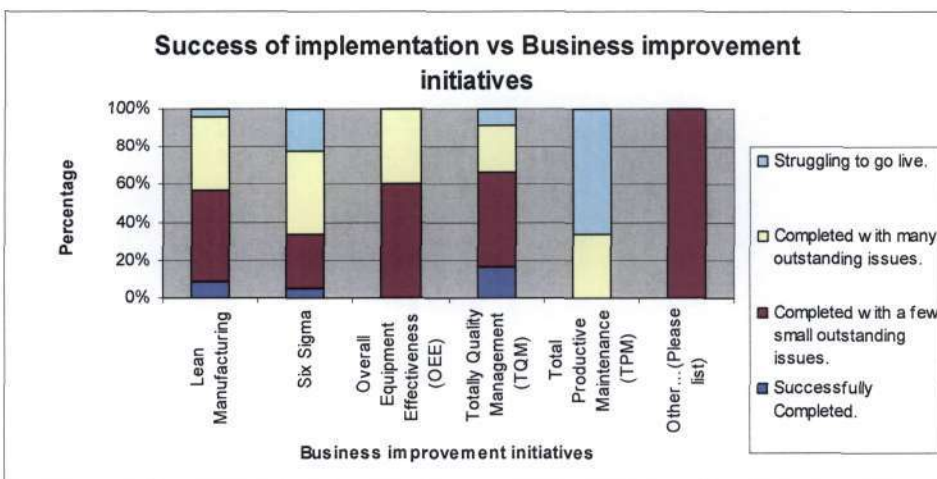
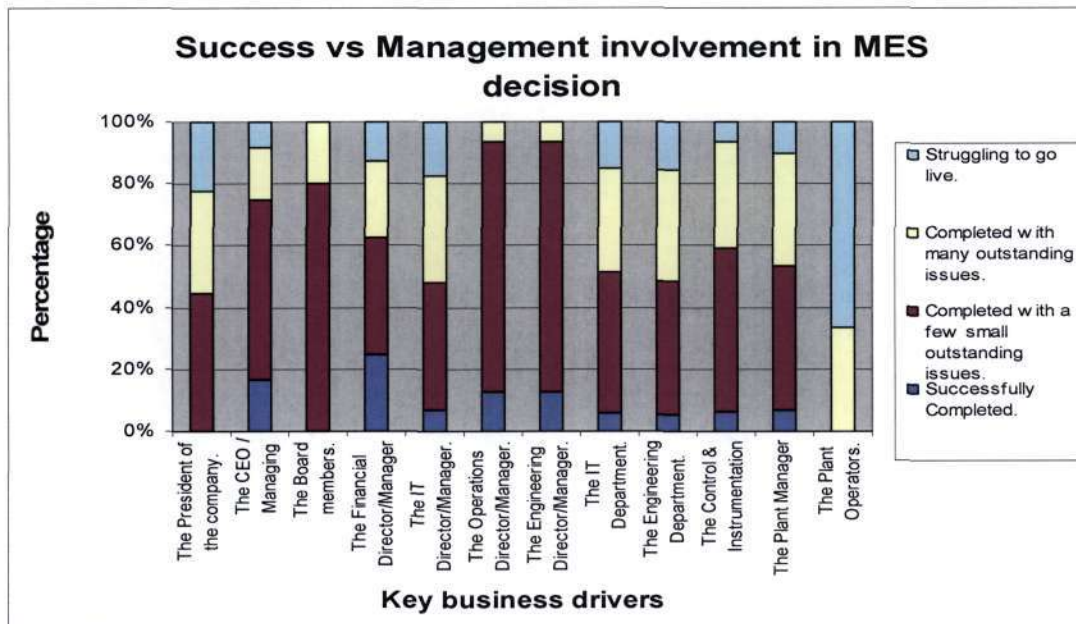


Figure 4.32: Implementation success vs. business improvement initiatives.

Introduction to Figure 4.32: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the business improvement initiatives used by the responding organisations.

In Figure 4.32 it seems that companies that used a business improvement initiative that was not listed, all completed the implementations with a few small outstanding issues. Of the companies that had OEE as a business improvement initiative 60% completed the implementations with a few small outstanding issues closely followed by Lean Manufacturing. In the chi-square test significantly more companies than expected that had lean manufacturing as business improvement initiative registered the implementation as complete with a few small outstanding issues.

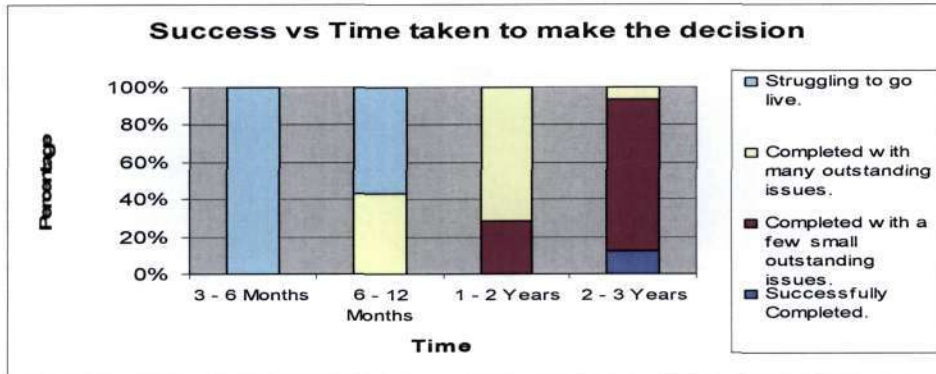


**Figure 4.33: Implementation success vs. management involvement in the MES decision.**

Introduction to Figure 4.33: This graph is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the involvement of management in the MES decision.

In Figure 4.33 it can be seen that in organisations where the operations and engineering managers/directors were involved, the implementations were most successful followed by organisations where the CEO/managing director and the board members were involved. In

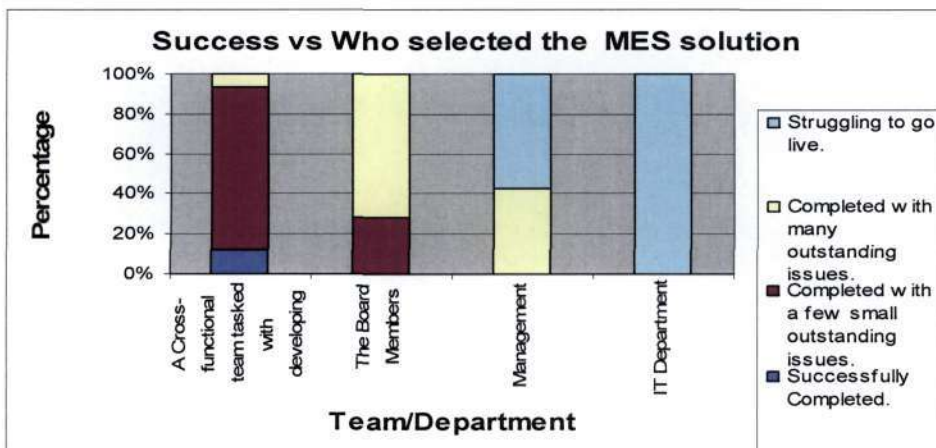
organisations where the plant operators were involved in the decision the organisation was not very successful with their implementation.



**Figure 4.34: Implementation success vs. time taken to make the decision.**

Introduction to Figure 4.34: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the time taken to make the MES decision by the responding organisations.

In Figure 4.34 it is clear that the longer organisations took to make their MES decision the more successful they were. It is assumed that the organisation took longer to make their decisions due to the fact that they spent more time on researching the MES decision process. The graph above suggests that for organisations to be successful in their implementations they need to spend at least more than a year on the MES decision to have a good chance of being successful.

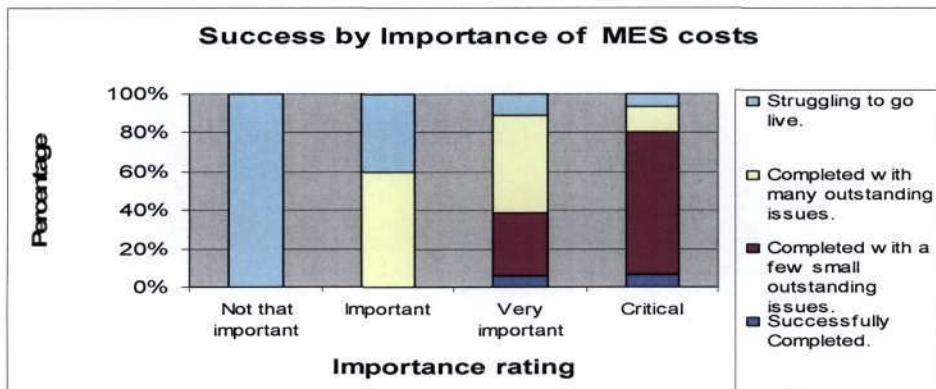


**Figure 4.35: Implementation success vs. who selected the MES solution.**



Introduction to Figure 4.35: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the team or department responsible for selecting the MES solution in the responding organisations.

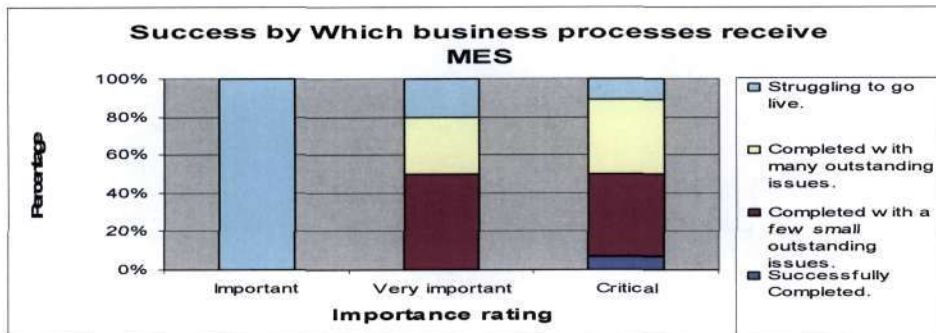
In Figure 4.35 it is clear that organisations that used cross functional teams to develop the business requirements were approximately 95% successful. Where the board members selected the solution only 25% were successful with few outstanding issues and 75% with many outstanding issues. In organisations where the IT department made the decision 100% of the organisations implementations were struggling to go live. The graph above suggests that organisations need to use cross functional teams to develop their business requirements to ensure implementation success.



**Figure 4.36: Implementation success vs. importance of MES costs.**

Introduction to Figure 4.36: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the importance of the total cost of the MES implementation to the organisations.

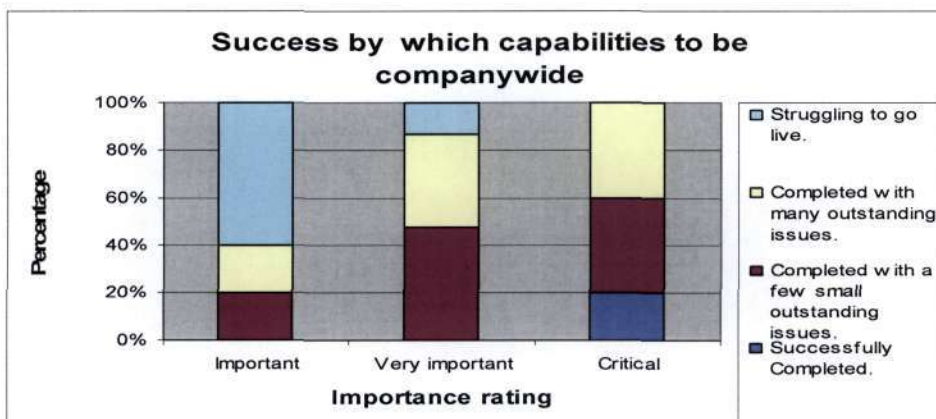
In Figure 4.36 it is clear that organisations that rated the internal decision of how much to spend on the MES solution as critical were 80% successful with their MES implementations. None of the organisations that rated this decision as not that important were successful with their implementation. The more important the decision of costs were to the organisations the more successful they were.



**Figure 4.37: Implementation success vs. which business processes receive MES.**

Introduction to Figure 4.37: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the importance to the organisation of the internal decision on which processes in the organisation should receive MES.

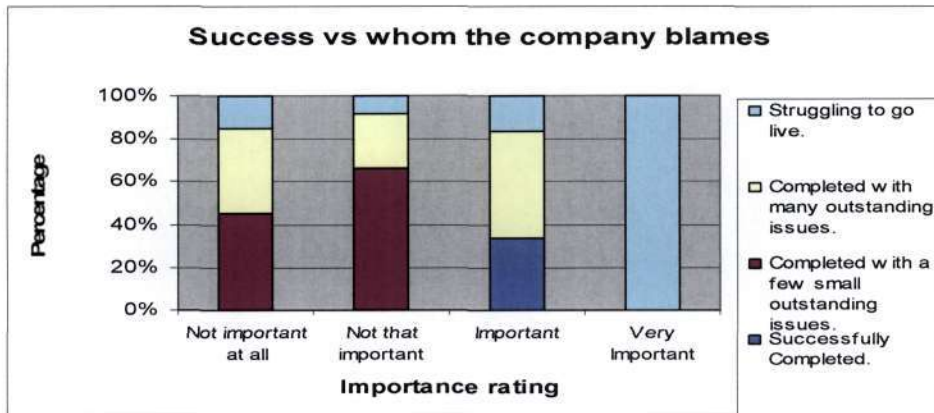
In Figure 4.37 it is once again clear that the organisations that deemed this internal decision as critical were allot more successful that organisations that rated the decision as important. The more important the decision of which processes should receive MES were to the organisations the more successful they were.



**Figure 4.38: Implementation success vs. which capabilities to be companywide.**

Introduction to Figure 4.38: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the importance to the organisation of the internal decision on which MES capabilities need to be companywide.

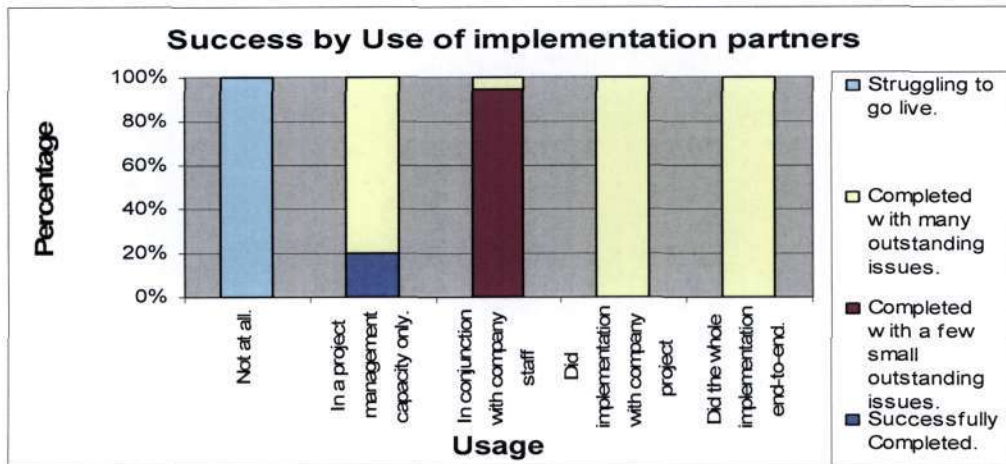
In Figure 4.38 it is once again clear that the organisations that deemed this internal decision as critical were allot more successful that organisations that rated the decision as important. The more important the decision of which capabilities should be companywide to the organisations the more successful they were. This importance of this decision to the organisations had a lesser impact on the success of the implementation as the previous two decisions.



**Figure 4.39: Implementation success vs. whom the company blames.**

Introduction to Figure 4.39: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the importance to the organisation of whom to blame when the implementation is not successful.

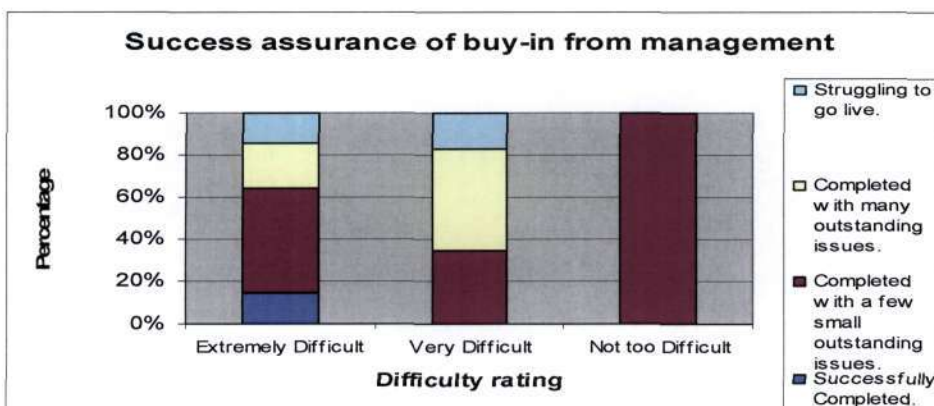
In Figure 4.39 organisations that place a priority on attaching blame to an individual or group were not successful in their MES implementations. In the group that rated this internal decision as important, 30% were very successful. This could be attributed to the fact that these organisations had focused groups with clear tasks to perform, and if there was a problem in their area they would be to blame. The organisations that did not place much emphasis on this decision seemed to be having a higher implementation success rate.



**Figure 4.40: Implementation success vs. use of implementation partners.**

Introduction to Figure 4.40: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the use of implementation partners by the responding organisations.

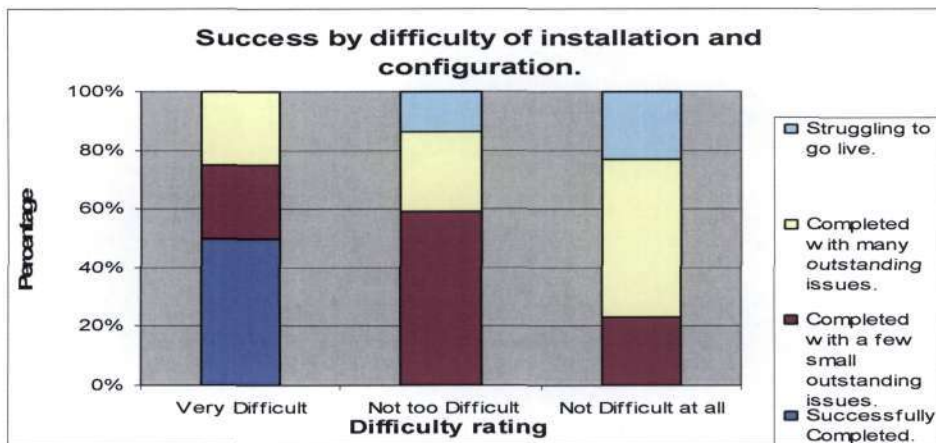
In Figure 4.40 it is clear that organisations that used implementation partners in conjunction with company staff had an almost 95% success rate with their MES implementations. Organisations that did not use implementation partners had 100% failure rate. Organisations that used implementation partners in a project management capacity had a 20% success rate. Organisations that used implementation consultants in conjunction with their own project managers or let the implementation partners do the whole implementation had very little success with their MES implementations.



**Figure 4.41: Implementation success vs. assurance of management buy-in.**

Introduction to Figure 4.41: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the importance of solid operations and management buy-in into the MES project.

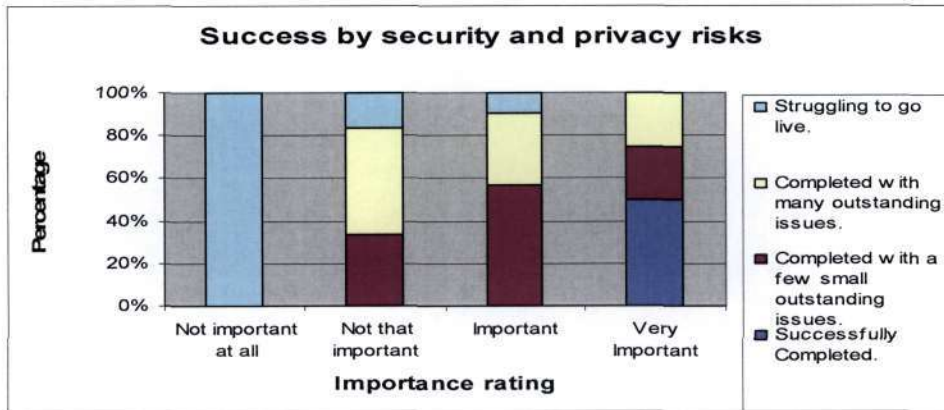
In Figure 4.41 organisations that rated the achievement of solid operations and management buy-in as not too difficult to secure were 100% successful in their MES implantations. Organisations that rated this buy-in as very difficult or extremely difficult had mixed successes in their MES implementations.



**Figure 4.42: Implementation Success vs. difficulty with installation and configuration.**

Introduction to Figure 4.42: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the difficulty that organisations experienced with the installation and configuration of their software and databases.

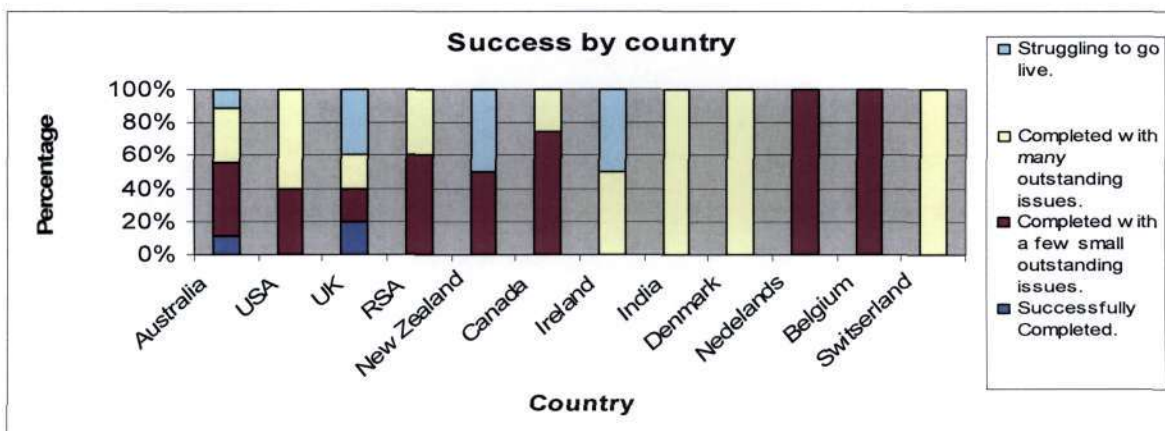
In Figure 4.42 organisations that found the installation and configuration of their software and databases very difficult had an almost 75% success rate in their implementations than organisations that found the installation and configuration not difficult at all but had only a 25% success rate in their implementations.



**Figure 4.43: Implementation Success vs. security and privacy risks.**

Introduction to Figure 4.43: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the importance of the decision on how much security and privacy risk the company should accept.

In Figure 4.43 organisations that rated this decision as important and very important were far more successful than organisations that did not place a lot of importance on this decision.



**Figure 4.44: Implementation Success by country.**

Introduction to Figure 4.44: This is a stacked horizontal bar graph which depicts the breakdown of the analysis of the implementation successes against the country in which the implementation took place.

Figure 4.44 is merely for interest sake and is no reflection on the implementation success across the world. Each country is not equally represented and the comparison is skewed.

The statistical analysis in this section is only the highlight of the total analysis. The full analysis of the responses to the research questionnaire is in the appendix.

## **4.6 Conclusion**

This chapter discussed various research findings from the research questionnaire. The chapter started with an analysis of the demographic description of the respondents to the research questionnaire, including responses per country and per industry vertical. It also analysed the functional designation and the status of the respondents' MES implementations. Chapter 4 analysed the business improvement initiatives in each organisation, and the MES functionality and support functionality that was implemented.

In the third part of the chapter the internal business drivers or internal pressures that exist within these organisations were analysed. An analysis on the expected performance issues or wins that were expected from the MES solution was done as well as an analysis of the level of involvement of the various stakeholders in the MES decision process. An analysis on the time that it took to reach the final decision was done and there was an in-depth look at the system that was, or was to be replaced by the new MES system.

Part four of this chapter looked at the implementation strategy and methodology. Firstly there was a description of the importance of certain IT decisions to the organisations which was followed by an analysis of the importance of the various contractual decisions. The involvement of the various stakeholders in the change management process was described followed by a description of the various costs of the MES implementation to these organisations. The organisations' experience in implementing certain stages of the implementation was analysed as well as the involvement of implementation partners. In part five the perceived wins or gains from implementing the MES solution were described.

Finally Chi-Square goodness-of-fit tests were conducted and cross-tabulations and analysis of the results were done.

Chapter 5 will provide the deductions, conclusions, viewpoints and recommendations from all the previous chapters. Chapter 5 will provide a short guideline on how to implement that MES solution. It will also discuss the validity of the hypothesis.



## **Chapter 5**

### **Conclusions and Recommendations**

#### **5.1 Introduction**

In this chapter all the data from the previous chapters is drawn together to provide final conclusions. Based on these conclusions recommendations are made regarding the strategy to be followed when planning on implementing an MES solution.

#### **5.2 Conclusions from the questionnaire responses received**

The following conclusions are made from the analysis and descriptions of the responses to the research questionnaire.

##### **5.2.1 Responses per country**

Of the responses received, 61% came from Australia, United States, United Kingdom, South Africa, New Zealand, Canada and Ireland. (This is mainly because the percentages of questionnaires sent out were almost in the same percentage groups as the percentages received back. This can be explained by the fact that most MES vendors are from the USA. These vendors targeted the USA and other English speaking countries before they started translating their software into European and other languages. Another explanation for the weak response from Europe and other non-English speaking countries is the language barrier.

##### **5.2.2 Responses by vertical industry**

Once again the number of responses correlated to the number of questionnaires sent to the specific vertical industries. The only recommendation is not to include an "Other" option in any questionnaire.

##### **5.2.3 Responses per Respondent Designation**

As per the two questions above the responses were representative of the questionnaires sent out. Within the 560 questionnaires emailed out to respondents, there were 242 different designations and the same proportion applied to the designations of the respondents who

replied. To achieve an accurate feel for the area of expertise of the respondents, their designations were grouped together into functional areas to enable the analysis of the function they specialise in. After analysing the functional areas the result was pretty much an even distribution among all the functions. The benefit of this is that the responses will be from different parts of the plant and will give well balanced conclusions after being analysed.

#### **5.2.4 Status of the MES Implementation**

Based on the responses received only 5% of the organisations had successfully completed their MES implementation. Organisations that had implemented but still had a few outstanding issues made up 46% and organisations that had implemented but still had many outstanding issues made up 36% of the respondents. This shows that approximately 95% of global MES implementations experience various problems during the process and this is what MES writers like McClellan and Gorbach allude to in their various articles.

#### **5.2.5 Business Improvement Initiatives**

Lean Manufacturing, Six Sigma and OEE are the main business improvement initiatives that the responding organisations used. This proves that these organisations all strive to improve their processes in some way or another. McClellan (1997) states that organisations cannot achieve improvements from their MES solutions unless they tie them to some form of business improvement initiative. These initiatives are all information reliant and the MES system can provide this information on a real-time basis.

#### **5.2.6 MES functionality implemented**

Most of the responding organisations chose to implement Materials Movement Management and Inventory Management and Tracking. This is interesting because it leads to the conclusion that the major area of focus in these plants is on the movement of material, the inventory levels and the overall tacking and tracing of each input and output. Most of this can be explained by new legislation ISA 95 which regulates the information requirements in certain organisations. In the pharmaceutical and food and beverage industries this regulation is at its strictest. Legislation ISA 95 dictates to the nuclear, aerospace and armaments industries that every single component must be traceable to its inception and in the other direction to exactly where it went.

The main focus on the support functionality is on maintenance management, statistical process control, quality control and document/product data management. All these functions except the last one are measurements of OEE. So most of the organisations are striving towards overall equipment effectiveness without realising it.

### **5.3 The MES Decision Process**

#### **5.3.1 Key Drivers for Implementing an MES Solution.**

The following MES decisions were rated as follows by the organisations.

The responses to the question on the importance of mapping customer orders to specific production runs in the MES decision process rated it as being between Not that important to Important. This decision would only be important to organisations that have Batch Production where the customer orders a specific product.

The responses to the question on controlling and dispatching orders in the MES decision process rated it as being between Not that important and Important. As with the case above this would only be important to organisations that have Batch Production where the customer orders a specific product.

The responses to the question on the importance of updating the scheduler with actual data (e.g., labour, material and machines) in the MES decision process rated it as being between Not that important and Important. This suggests in conjunction with the responses to the questions above that the majority of the respondents produce the same product day in and day out in a continuous process.

The responses to the question on the importance in defining and enforcing production procedures and business rules the MES decision process rated it as being Important for most of the respondents. A clear understanding of production procedures is very important in a plant to avoid mistakes and rejects.

The responses to the question on the importance of automatically alerting production personnel to deviations from production rules in the MES decision process rated it as being Important.

The responses to the question on the importance of dispatching and coordinating material and required information for unit operations in the MES decision process rated it as being Important to Not that important.

The responses to the question on the importance of real-time production reporting (e.g., materials usage and scrap) in the MES decision process rated it as being Important.

The responses to the question on the importance integrating quality management data in the MES decision process rated it as being Very important to some and not that important to others. The conclusion made here is that this factor is industry specific.

The responses to the question on the importance of providing real-time feedback and automatic alerts to positively affect the run in the MES decision process rated it as being Very important and so it should be. If anything goes wrong in a plant, personnel need to react immediately to prevent damage and wastage.

The responses to the question on the importance defining and enforcing specific equipment, routes, operator and material combinations in the MES decision process rated it as being Not important at all

### **5.3.2 Business divers that contribute towards the MES decision**

Of these the external pressures like pressure to improve operational performance and competitive advantage rated very heavily towards MES that the internal pressures like increase quality and ROI. This proves that whoever is measured against these external factors has more decision weight than the internal person.

### **5.3.3 Performance issues required from the MES solution**

The factors that rated the highest here were increased production yields, labour, plant utilisation and asset utilisation. These are all factors of improving performance with current investment, getting more out of the assets that the organisation already has. OEE

#### **5.3.4 Level of involvement of stakeholder in the MES decision**

Here the right people were involved, the plant manager, C&I department, engineering and operations. These are the people that will be tasked to make the MES solution work and that will have to maintain it. The people that are needed to drive the project from a change management perspective are absent - the senior management. These organisations will struggle with operator and worker acceptance of the new system.

#### **5.3.5 Timeframe of the MES decision**

Here there is a strong correlation between the level of senior management involved and the timeframe of the decision. The higher the level of management involved the longer the decisions take (see Graph 4.33 and 4.34).

#### **5.3.6 The system that was to be replaced by the MES solution**

Most organisations had trouble with the timeliness of the information and wanted the information in real-time. Integration of applications and multi vendor applications represented another hurdle. Reports did not include all the data and thus none of the reports can be trusted until verified.

### **5.4 Implementation Strategy and Methodology**

#### **5.4.1 The importance of internal IT decisions in the organisation.**

Here the processes that should receive the MES far outweighed system security or somebody taking ownership for the successful implementation. The human element in a plant will always choose gains above security or doing the implementation successfully.

#### **5.4.2 Which contractual considerations are important**

Here any interaction with the software vendor was prioritised above internal issues. Organisations were handing over control to the software vendor and were following the vendor's decisions blindly.

#### **5.4.3 Involvement of stakeholders in implementing change management**

Once again the people responsible to maintain the system are there but the people that need to drive it to ensure its success are conspicuously absent.

#### **5.4.4 Implementation experiences with different stages of the implementation**

Here the problem areas were training, developing a solution, solution design, buy in from operation and management and project definition and scoping. These factors all point to a lack of knowledge about an MES implementation.

#### **5.4.5 Implementation Partners**

Here the organisations preferred to have the implementation partners work in conjunction with the organisation's staff during the implementation to ensure a knowledge transfer.

### **5.5 Recommendations**

#### **5.5.1 Introduction**

The following questions and strategic decisions are recommended for any company that is planning to implement an MES solution and are based on the literature studied for this dissertation and the analysis of the responses to the research questionnaire.

#### **5.5.2 Why are you implementing an MES solution?**

This question must be addressed before starting the implementation. MES solutions fit perfectly with today's continuous improvement strategies like Six Sigma, Lean Manufacturing, Overall Equipment Effectiveness, Total Quality Management and others. These improvement strategies all require the ability to gather real-time, accurate and visible measurements of a process in order to create improvement initiatives. AMR Research states that at a fraction of the cost and time of an ERP initiative, an MES platform provides visibility into accurate, high-velocity information about current production performance (Gorbach, 2005).

With any continuous improvement strategy, management must first decide which processes will be improved, the metrics for measuring improvement and the key performance indicators (KPI's) that will indicate a successful strategy. If management decides to reduce downtime, the KPI will be different from that used to determine quality. Therefore, it is crucial to determine before evaluating software packages which improvements will have the greatest impact on the organisation/plant and how initiatives will be measured. Organisations that have business improvement initiatives implemented are more successful at implementing MES

solutions. From the chi-square test conducted on the respondents to the research questionnaire an above average number of organisations that had lean manufacturing as a business improvement initiative, were successful with their MES implementations. It is recommended that organisations follow a business improvement initiative in conjunction with the MES implementation.

### **5.5.3 Do you have the right level of management buy-in?**

Because MES systems may change the way organisations operate, senior management must be on board throughout the evaluation, selection and implementation process, as it requires measurements and metrics that can make workers believe their individual performance is being measured. Therefore, it is imperative that senior management set the tone and send out the correct message that the continuous improvement initiative is about improving process, not judging individuals. If the change management is not driven from the top it has little chance of being successful.

### **5.5.4 A Pilot versus a Complete Rollout?**

While a full roll out may appear quicker, it involves more effort and organizational risk than a pilot. It is important to remember that expanding the MES solution to other production lines and plants will be much faster and less expensive after a successful pilot.

#### **Choosing the Pilot Location**

When selecting the area for an MES pilot, a company should examine several characteristics: What location best represents the other locations for the planned rollout? What location has the most progressive personnel who welcome new ideas? What production area will involve the least cost for implementing the system?

#### **Championing the pilot to all participants**

Attention now turns to the workers who will be affected by the pilot. Communication is crucial because some workers may feel burdened by the new system or fear it will measure individual performance. It is very important to create a communication plan that motivates the people impacted by the pilot.

The operations team will be the first group impacted by the pilot and any technical issues must be resolved quickly to maintain operator confidence and interaction with the system. Other

groups that need to be considered are: IT/MIS department, maintenance department, engineering department, control and instrumentation, process, supply chain and quality/continuous improvement department

### **Defining the Pilot**

With all the necessary departments involved, the first meeting should gather each department's objectives and goals. For example, the maintenance department may have a goal of reducing downtime by 10%. Not all the goals need to be financial in nature. Manufacturers who leverage the visibility that an MES solution can provide to the executive/corporate level often see much higher returns than those that use it simply for local cost reduction measures. The next step is to create a specification outlining the pilot's goals, the current setup and the company requirements. This outline will be the foundation for the solution evaluation process.

### **5.5.5 Selecting a Solution Provider**

The specification will be the main document used for evaluating different solutions. It is important that a solution provider understands the manufacturer's goals as well as provides the right software. MES solutions are complex, and manufacturers will usually achieve better results when they select a solution provider instead of software alone. A complete solution provider is advantageous because the provider provides the practical experience, professional services, and technology necessary to deliver the solution on-time and on-budget.

- They create a solution that fits the company's needs instead of just selling software licenses.
- They provide services when needed to ensure optimal configuration and provide training to show plant personnel how to maintain and expand the system at later stages.
- They provide support after the sales service in case of unplanned changes/issues and also provide periodic support to continuously improve the depth and breadth of system interaction that results in increased benefit to the enterprise.
- They ensure that the system can be expanded to the full enterprise without significant redevelopment and ensure a low total cost of ownership (TCO).
- Finally they ensure that organisational goals are met or exceeded.



The last question comes down to the relationship with the solution provider. Whether choosing a large or a small company, the solution provider should understand the company's specific needs.

### **5.5.6 Implementing the Pilot Project**

How the project is run is just as important as how the project is specified. In general there are four major phases of a project:

1. Detailed definition of the pilot schedule,
2. Configuration of the pilot schedule,
3. Installation of the pilot schedule,
4. Optimization of the pilot schedule.

The rollout plans are decided on after the successful pilot. All four phases are critical to the success of the pilot, and require a high level of agreement and interaction to work properly.

#### **Phase 1: Detailed definition**

The detailed definition phase involves the project team comprising people from the MES solution provider and end users. A meeting should be scheduled to scope out the project under the following topics: review of technical details, Functional Requirements Specification Document (FRS) and the internal review and customer acceptance. The Functional Requirements Specification Document (FRS) will include all the requirements from training, hardware, software, networking, etc. perspective.

#### **Phase 2: Configuration of the pilot**

The configuration of the pilot is the primary responsibility of the MES solution provider with participation from internal organisational staff to ensure a skills transfer; however, it should be an open process where the end user has periodic reviews and regular status updates on the software configuration, internal review and testing and customer acceptance

After finishing the complete system test against the Functional Requirements Specifications Document, the next step is to perform a factory acceptance test (FAT). The FAT demonstrates to the end user that the system is complete and ready for installation. This is a critical step for

customer review and acceptance, and where problems that could impact the success of the implementation need to be evaluated. The customer should include the operations staff that will use the system. This ensures operational issues are identified prior to installation. Only after everyone on the project team is convinced the project is ready for installation should the next phase of the project begin.

### **Phase 3: Installing the solution**

Typically this part of the pilot has the following components.

- Site Commissioning and Customer Acceptance

While the site commissioning can be the shortest in duration of all the phases of the project, it is by far the most critical. Typically during this phase, the users begin operating the system. Items that should be covered during this phase of the project are the operator training, administrative and programming training, user training on data analysis, and organisational stakeholder's review of received information. This can also be compared to the information from the previous system.

Once the system is operational, all training and final acceptance testing should be done on the system to remedy any final issues.

- Optimization

MES projects, just like process improvement initiatives, are continual. MES solutions offer even bigger returns when they are used to drive continuous improvement, not just for cost reduction measures. The initial implementation may need optimization and fine tuning. This fine tuning should be done in conjunction with the MES solution provider because it has the best understanding of how to analyze and optimize the solution. This part of the project needs to be viewed more as a long-term transition to rollout. The MES solution provider should do an extended handoff to help the users understand how to interpret the data and how to modify the system to meet their future needs.

#### **5.5.7 The Final Phase: Rollout**

Much of the experience gained during the pilot will facilitate the rollout. For example, significant knowledge should have been gained during the optimization phase to determine the optimal time and location(s) for the rollout. Crucial information gathered should have been documented to make a best practices document. During the rollout, the MES project manager

may use these practices to replicate prior successes or make adjustments to accommodate any challenges recognized during the implementation phase. These lessons directly correlate to time and costs savings in the rollout.

There is no right or wrong time to rollout; the pilot's function is to prove that the concept works. Managing the pilot as a process will yield operational visibility into the plant's operations. Proper management of the MES solution pilot is key to achieving the benefits of an MES solution. The pilot's success is largely a result of good coordination between the solution provider and the end users in which the solution provider is a partner not merely a vendor. When the team comprising members of the solution vendor, external consultants and the end users are satisfied that all the objectives and requirements set for the pilot had been achieved, the pilot can be regarded as a success.

At this point the stakeholders in the organisation should have a good idea of how to continue and make a resounding success of the implementation.

## **5.6 Conclusion and Recommendations**

Implementing a Manufacturing Execution System (MES) solution is a very complex process that demands in-depth upfront planning of every step of this process, for it to have a chance of being successful. During the research it became clear that the problem areas in the implementation process are a combination of the following.

- Organisations struggle to do a proper initial project definition and scoping
- Organisations do not get high level commitment from senior managers in the organisation to drive the change management initiatives
- The MES project management team is not chaired by a senior member of management with vast project management experience
- A proper information requirements analysis is not done up-front and the compatibility between certain systems is not ensured before the start of the implementation resulting in major integration issues between systems containing various bits of information.

- The solution is not fully designed, from the highest level to the lowest level, before the onset of the implementation.
- The hardware is not specified correctly and this causes installation and configuration problems.
- Training is not done during the implementation of the pilot to ensure that operators are totally comfortable with the system. Documentation in most cases is non-existent.
- The MES vendor is not thoroughly investigated to ensure that they have a solution that works. Several visits need to be made to the vendor's reference sites to ensure that all their projects were successful. If using an implementation partner, visit their previous projects and meet with the organisations stakeholders to ensure the competence of the implementation partner

There is strong evidence in the statistical analysis that suggests that the hypothesis formulated in Chapter 3, all MES implementations that are not thoroughly scoped, planned and properly specified before the implementation commences and that are not driven from a very high level in the organisation will not be successful and the organisation will struggle for a very long time to get a fully functional MES system in the organisation, is proved to be true.

The final recommendation of this research project to organisations is to research MES thoroughly and once there is a good level of expertise in the organisation plan the process from top to bottom and bottom to the top. Organisations should use small pilot implementations to test the feasibility of MES in certain sections of the business. Finally and probably most important, organisations have to ensure high level management commitment to drive the project from the top.

The End



UNIVERSITY OF  
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11 DECEMBER 2006

MR. GJ ENGELBRECHT (202525327)  
GRADUATE SCHOOL OF BUSINESS

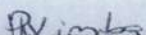
Dear Mr. Engelbrecht

**ETHICAL CLEARANCE APPROVAL NUMBER: HSS/06840A**

I wish to confirm that ethical clearance has been granted for the following project:

**"Successfully implementing a manufacturing execution systems (MES) Solution"**

Yours faithfully

  
.....  
MS. PHUMELELE XIMBA  
RESEARCH OFFICE

cc. Faculty Office (Christel Haddon)  
cc. Supervisor (Prof. S Lubbe)

P O BOX 3066  
ASSAGAY  
3624  
4 April 2007

TO WHOM IT CONCERNS

PROOFREADING OF DISSERTATION

**Successfully implementing a manufacturing systems (MES) solution**

Student: Deon Engelbrecht

Student number: 202525327

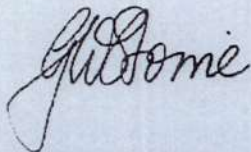
I have proofread the dissertation correcting errors of spelling, grammar and syntax. I have suggested improvements in punctuation.

I have also pointed out where the meaning is not clear and in some instances I have made suggestions to correct the lack of clarity.

Where the format is not consistent I have pointed this out.

I have pointed out areas in the referencing and bibliography that do not conform to conventions.

Yours faithfully



Gavin W Storrie

B A (Hons) UED

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FOR OFFICE USE ONLY: Respondent Code \_\_\_\_\_  
Voluntary Research Questionnaire  
**Successfully Implementing a Manufacturing Execution Systems (MES) Solution.**

Researcher : G.J. Engelbrecht  
Supervisor: Prof. Sam Lubbe  
MBA Dissertation of the Graduate School of Business  
University of KwaZulu-Natal, South Africa.

**Note to the respondent:**

Please will you assist me to determine the Critical Success Factors for implementing a successful Manufacturing Execution System (MES). This study will enable us to be able to provide companies, which are looking to implement a possible MES solution, with a guideline to highlight each of the steps of the selection process right down to the final signoff of the completed implementation.

Although we would like you to help us, you do not have to take part in this survey.

All answers in this questionnaire are for research purposes and will not be used for any other purpose than academic research.

**How to complete the questionnaire:**

Please answer the questions as truthfully as you can. Also, please be sure to read and follow the instructions for each question.

The questions were designed in such a way that you should feel comfortable to answer them.

If however you do not feel comfortable answering a question please just leave it blank.

You can mark each question by placing an X or in some cases a number from 1 to 5.

Thank you very much for completing this questionnaire.

G. J. Engelbrecht

## Part 1: Permission to use my responses for academic research.

I hereby give Mr. G. J. Engelbrecht permission to use my responses for research purposes, towards his MBA dissertation, provided that my identity or the identity of this company is not revealed in any way in the dissertation.

Initials and Surname:

Email Address:

Phone Number:

Signature:

Date:

## Part 2: General Questions.

Please select your answer by placing an X in the box.

1 Into which of the following industry vertical does your company fall?

- Automotive.
- Food and Beverage.
- Textiles.
- Forestry
- Pulp and Paper.
- Metals.
- Mining & Minerals.
- Oil and Gas.
- Packaging.
- Water and Waste.

2 Is your MES implementation...?

- Successfully Completed.
- Completed with a few small outstanding issues.
- Completed with many outstanding issues.
- Struggling to go live.
- Aborted

3 Does your company use any of the following business improvement initiative?

- Lean Manufacturing
- Six Sigma
- Overall Equipment Effectiveness (OEE)
- Totally Quality Management (TQM)
- Total Productive Maintenance (TPM)
- Other...(Please list)



4 Which of the following MES functionality has your company implemented?

- Planning Systems.
- Order Management.
- Workstation Management.
- Inventory Management & Tracking.
- Material Movement Management.
- Exception Management

5 Which of the following MES support functionality has your company implement ding?

- Maintenance Management.
- Time and Attendance.
- Statistical Process Control.
- Quality Assurance.
- Process Data/ Performance Analysis.
- Document/Product Data Management.
- Genealogy/Product Traceability.
- Supply Chain Management.
- Warehouse Management.

### Part 3: The MES decision.

Using the following key, please answer the following:

- 5 - Critical                      4 - Very Important                      3 - Important  
2 - Not that Important                      1 - Not Important at All

6 Please rate the following key drivers for implementing a MES solution by your company?

- Mapping customer orders to specific production runs.
- Controlling and dispatching orders.
- Updating the scheduler with actuals (e.g., labour, material and machines).
- Defining and enforcing production procedures and business rules.
- Automatically alerting production personnel to deviations from production rules.
- Dispatching and coordinating material and required information for unit operations.
- Real-time production reporting (e.g., materials usage and scrap).
- Integrating SPC/SQC (quality management).
- Providing real-time feedback and automatic alerts to positively affect the current run.
- Defining and enforcing specific equipment, routes, operator and material combinations.  
for a particular work order or product.

7 Please rate the following business drivers as contributors to the decision in 6 above?

- Pressure to improve operational performance.
- Competitive advantage in price and service.
- Customers demanding shorter order cycle time.
- Customers demanding reduced prices.
- Corporate objective to reduce inventory.
- Pressure to improve return-on-invested-capital.
- Increase product quality.

8 Please rate the following performance issues that were required from the MES solution?

- Improved OEE.
- Increased Asset Utilization.
- Increased Plant Reliability.
- Increased Energy Efficiency.
- Increased Plant Utilization.
- Increased Labour Efficiency.
- Increased Production Yield
- Improved Variability Control

Using the following key, please answer the following:

5 - Permanently Involved

4 - Very Involved

3 - Involved

2 - Small Involvement

1 - Not Involved at All

9 Please rate the involvement of the following people (stakeholders) in the MES decision?

- The President of the company.
- The CEO / Managing Director.
- The Board members.
- The Financial Director/Manager
- The IT Director/Manager.
- The Operations Director/Manager.
- The Engineering Director/Manager.
- The IT Department.
- The Engineering Department.
- The Control & Instrumentation Department.
- The Plant Manager
- The Plant Operators.

10 How long did it take the company to make the final decision to implement a MES?

- 1 Month
- 2 - 3 Months
- 3 - 6 Months
- 6 - 12 Months
- 1 - 2 Years
- 2 - 3 Years

11 Which of the following was applicable to the system that was MES's predecessor?

- The systems was deliberately low-tech.
- Information supplied was not timely & accessible.
- Not flexible enough for shop-floor changes.
- Operator interfaces were complicated and intimidating.
- Integration is a nightmare to other systems.
- Made up of multi vendor applications grouped together.

#### Part 4: Implementation strategy/methodology.

Using the following key, please answer the following:

5 - Critical                      4 - Very Important                      3 - Important  
2 - Not that Important                      1 - Not Important at All

12 Please rate the following internal IT decisions according to their importance as perceived in your organisation.

- How much should the company spend on MES?
- Which business processes should receive MES?
- Which MES capabilities need to be companywide?
- How good does the MES services need to be?
- What security and privacy risks will the company accept?
- Whom does the company blame if the MES initiative fails?

13 Please rate the following contractual considerations according to their importance as perceived in your organisation.

- Collaborative between the MES software vendor and your company.
- Clear and open communication the MES software vendor and your company.
- Negotiate of payment terms with the MES vendor.
- Including the "professional services" piece in the MES contract.
- Defining the service levels that must be met for the implementation to be complete.

Using the following key, please answer the following:

Using the following key, please answer the following:

- 5 - Permanently Involved
- 4 - Very Involved
- 3 - Involved
- 2 - Small Involvement
- 1 - Not Involved at All

14 How involved were the following people in helping to implement the correct change management procedures in your organisation.

- The President of the company.
- The CEO / Managing Director.
- The Board members.
- The Financial Director/Manager
- The IT Director/Manager.
- The Operations Director/Manager.
- The Engineering Director/Manager.
- The IT Department.
- The Engineering Department.

15 Please indicate next to each cost, approximately how much your company spent on each of these specific MES implementation costs.  
(Please round your costs to the closest 1000 US\$)

- US\$  Software Costs
- US\$  Hardware Costs
- US\$  Consulting Costs
- US\$  Overtime Costs
- US\$  Training Costs

Using the following key, please answer the following:

- 5 - Extremely Difficult
- 4 - Very Difficult
- 3 - Not too Difficult
- 2 - Not Difficult at all
- 1 - No Problem (Easy)

16 What was your companies experience with each of the following challenges in the implementation of your MES solution.

- Project definition and scoping of the project.
- Assurance of solid buy-in from operations and management.
- MES Project team management.
- Design and creation of interfaces to ERP, document, labour and other systems.
- Information requirements analysis.
- High-level solution design
- Development of a functional MES solution.
- Software and database installation and configuration.
- Training and documentation

17 Of the following list of reasons for potential MES implementation failure, which were applicable on you companies implementation.

- The project scope was too broad,
- Attempted to cover too many aspects of the manufacturing environment.
- An integration nightmare was created by attempting to connect to too many data sources.
- MES package was forced to fit an environment for which it was not optimally suited.
- Over customization of software.
- too many custom delays and changes.
- Too much reliance on the MES vendor.

18 Who in your company chose the right MES solution.

- A Cross-functional team tasked with developing business requirements.
- The Board Members
- Management
- IT Department
- Engineering Department.

19 During the implementation, Implementation partners were used in the following ways.

- Not at all.
- In a project management capacity only.
- In conjunction with company staff
- Did implementation with company project managers.
- Did the whole implementation end-to-end.

20 What benefits, if any did you receive from using Implementation partners.

- Their manufacturing process knowledge.
- Their specific vertical market knowledge.
- Their proven MES implementation experience.
- Their understanding of your process and how it could be improved.
- Familiarity with mayor software solutions and their functionality.
- Their integration experience into your companies other information systems.

21 Which of the following are specific future requirements for your companies MES solution.

- Enterprise Integration towards a collective global enterprise
- Distributed Organization that link to distributed knowledge bases.
- Heterogeneous Environments that accommodate heterogeneous software and hardware.
- Interoperability between software, programming languages and IT platforms.
- Open and Dynamic Structures that integrate to new sub systems.
- Integration of humans with software and hardware



24 Which part of the MES implementation process, if given the opportunity, would have been done differently and for what reason.


25 Would you like a copy of the completed dissertation?

<input type="checkbox"/>	Yes
<input type="checkbox"/>	No

Thank you again for helping with this survey.

		A	B	C	E	F	G
		Introduction / Definition / Overview	Key drivers / benefits of MES	Core Functions & Functionalities	Support Systems / Interfacing / Integration	Challenges and Risks to System implementation	Implementation Strategy & Methodology
Introduction 2 MES's	1						
MES - A Concept Note (TATA)	2						
MES Explained: A high level vision	3						
Implementing MES's: 5 key steps	4						
Agent based Syst 4 Intelligent mfg.	5						
How a next-gen MES can drive flex mfg	6						
How 2 choose a Manuf System	7						
The MES Advantage	8						
Global Mfg: MES & beyond	9						
Why is plant floor software different?	10						
AMR find Global MES market \$1B	11						
Distributed MES's: A workflow perspective	12						
Six it decisions your it people shoulnt make	13						
POMS MES in Popharma	14						
Safeway Manf Div: MCS	15						
New operator interface for Poseidon MES	16						
Plant wide Info: MES for SMB	17						
Don't overlook MES in PLM strategy	18						
MES: The 1 stop info source	19						
Selecting & using a MES	20						
MES: A look back, a look forward	21						
MES help achieve reduced cycle, 0 error etc	22						
Bridging the Gap between MRP/ERP & Shop f	23						
MES deal a winning hand	24						
Expert advice for next Gen Manufacturing	25						
MES definition work continues	26						
The Collaborative Effect	27						
Execution Sys: The heart of intelligent mfg	28						
Real-Time Manufacturing Maximises Prod	29						
Manf Planning & exec softw interfaces	30						



MES: Bridging the info gap between Boardr	31					
Promise of greater eff thr r/t data MES	32					
MES makes its way to the shop floor	33					
MES: Moving to the next level - Special Repo	34					
Successful MES implementation hinges on SI	35					
MES :MES Defined	36					
Intergrating MES and Enterprise Systems	37					
Streamline Shop Floor Ops by using MES	38					
The MES Performance Advantage	39					
MES provides LT revenue and Market benefits	40					
Getting IT Right	41					
Implementation Best Practices	42					
Engineers play a critical role	43					
6 Things to consider b4 a maj SW impl.	44					
Successful Impl Challenges and Solutions	45					
Successful Software Implementations	46					
ERP Implementation - The Traps	47					
Applying 6O 2 SW implementation projects	48					
Talk 2 your Plants	49					
Save Time & Money: Outsource SW impl.	50					
Manf in the age of eBus: Role of MES	51					
Life, the universe and MES	52					
MES - Is the tail wagging the dog?	53					
Is MES the answer 4 competitiveness in Ind?	54					
MES promises significant ROI in 6 mths	55					
Metals Ind - Does MES fail 2 meet requirmts?	56					
Boost Bus Results & gain quik ROI with MES	57					
Demand 4 CPM/MES strong in all key makts.	58					
Leveraging MES 4 global visi of shop F data	59					
MES	60					
MES: Will E-comm drive it into auto?	61					
MES Intergration and Intelligence	62					
MES Considerations	63					
See clearly into Plant-Floor Applications.	64					
AMR reviews netweaver for Manufacturing	65					
Developing MES using Labview.	66					

<b>Manf Exec Systems: MES defined</b>	<b>67</b>					
<b>MES in metals</b>	<b>68</b>					
<b>MES (texMES)</b>	<b>69</b>					
<b>MES market heat up</b>	<b>70</b>					
<b>Manf Exec Systems heats up</b>	<b>71</b>					
<b>MES Leveraging data for comp adv. Part 1</b>	<b>72</b>					
<b>MES Leveraging data for comp adv. Part 2</b>	<b>73</b>					
<b>Do Chinenese Enterprises nees MES?</b>	<b>74</b>					
<b>The challenges of intergrating MES</b>	<b>75</b>					
<b>What are MES's</b>	<b>76</b>					
<b>IET MES for IC Packaging and testing.</b>	<b>77</b>					
<b>ERP (MRPII) &amp; MES Selection Process</b>	<b>78</b>					

	I	J	K	L	M	P
	Implementation Partner (SI) & Consultants	Requirements for next generation MES	Choosing MES (options)	Questions & Change Management before impl MES	Implementation Costs	a Case / Case Study for MES
Introduction 2 MES's						
MES - A Concept Note (TATA)						
MES Explained: A high level vision						
Implementing MES's: 5 key steps						
Agent based Syst 4 Intelligent mfg.						
How a next-gen MES can drive flex mfg						
How 2 choose a Manuf System						
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Global Mfg: MES & beyond						
Why is plant floor software different?						
AMR find Global MES market \$1B						
Distributed MES's: A workflow perspective						
Six it decisions your it people shoulnt make						
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Safeway Manf Div: MCS						
New operator interface for Poseidon MES						
Plant wide Info: MES for SMB						
Don't overlook MES in PLM strategy						
MES: The 1 stop info source						
Selecting & using a MES						
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MES help achieve reduced cycle, 0 error etc						
Bridging the Gap between MRP/ERP & Shop f						
MES deal a winning hand						
Expert advice for next Gen Manufacturing						
MES definition work continues						
The Collaborative Effect						
Execution Sys: The heart of intelligent mfg						
Real-Time Manufacturing Maximises Prod						
Manf Planning & exec softw interfaces						

MES: Bridging the info gap between Boardr						
Promise of greater eff thr r/t data MES						
MES makes its way to the shop floor						
MES: Moving to the next level - Special Repo						
Successful MES implementation hinges on SI						
MES :MES Defined						
Intergrating MES and Enterprise Systems						
Streamline Shop Floor Ops by using MES						
The MES Performance Advantage						
MES provides LT revenue and Market benefits						
Getting IT Right				XXXXX		
Implementation Best Practices						
Engineers play a critical role						
6 Things to consider b4 a maj SW impl.						
Successful Impl Challenges and Solutions						
Successful Software Implementations						
ERP Implementation - The Traps						
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See clearly into Plant-Floor Applications.						
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<b>Manf Exec Systems heats up</b>						
<b>MES Leveraging data for comp adv. Part 1</b>						
<b>MES Leveraging data for comp adv. Part 2</b>						
<b>Do Chinese Enterprises need MES?</b>						
<b>The challenges of integrating MES</b>						
<b>What are MES's</b>						
<b>IET MES for IC Packaging and testing.</b>						
<b>ERP (MRPII) &amp; MES Selection Process</b>						

## **Bibliography:**

Biddle, J. 2006. *Global Manufacturing: MES and Beyond Benchmark Report*. Boston: Aberdeen Group Inc.

Bruhn, Tom. 1997. Successful MES implementation hinges on knowledgeable system integrator. *Pulp & Paper* [Online] May 1997. Retrieved on 3 October 2006 from [http://www.findarticles.com/p/articles/mi\\_qa3636/is\\_199705/ai\\_n8760433](http://www.findarticles.com/p/articles/mi_qa3636/is_199705/ai_n8760433)

Cagna, J., Tschaikovsky, J., Lennon, C., Kohn, S. 1999. *Implementing Manufacturing Execution Systems: Five Keys to Success*. New York: Computer Sciences Corporation. Retrieved on 4 October 2006 from <http://www.csc.com/industries/healthcare>

Chang, J. IET MES (Manufacturing Execution System) For IC Packaging & Testing. White Paper by Infoeverest, IET. TW, China. Retrieved on 9 October 2006 from <http://www.infoeverest.com>

Cosgrove Ware, L. 2003. Save Time and Money: Outsource Software Implementation. *CIO Magazine* [Online] Feb 1. Retrieved on 4 October 2006 from <http://www.cio.com>

Davis, A., Martin-Gill, W., Sherdel, W., Swedenburg, K. 1999. *New Operator Interface For The Poseidon Manufacturing Execution System*. Paper delivered at the 1999 Systems Engineering Capstone Conference, University of Virginia. Unpublished. pp. 55–60.

Dorgan, S.J. and Dowdy, J. 2004. When IT lifts productivity. *The McKinsey Quarterly*, 2004 Number 4 [Online Members Edition]. Retrieved on 27 September 2006 from [http://www.mckinseyquarterly.com/article\\_print.aspx?L2=13&L3=11&ar=1477](http://www.mckinseyquarterly.com/article_print.aspx?L2=13&L3=11&ar=1477)

Feld, C.S. & Stoddard D.B. 2004. Getting IT Right. *Harvard Business Review* [Online] February. Retrieved on 16 August 2006 from <http://www.hbr.org>

Feng, S.C. 2000. Manufacturing Planning and Execution Software Interfaces. *Journal of Manufacturing Systems* [Online]. Retrieved on 3 October 2006 from [http://www.findarticles.com/p/articles/mi\\_qa3685/is\\_200001/ai\\_n8881618](http://www.findarticles.com/p/articles/mi_qa3685/is_200001/ai_n8881618)

Frantz, P.A., Southerland, A.R. & Johnson J.T. 2002. ERP Software: Implementation Best Practices. *Educause Quarterly*, Number 4 2002. pp. 38-45

Fraser, J. 2004. The MES Performance Advantage: Best of the Best Plants Use MES. *Industry Week Best Plants 1998 – 2002 Analysis*. Industry Directions Inc. Retrieved on 18 August 2006 from <http://www.industrydirections.com>

Fraser, J. 2004. *Boost Business Results and Gain Quick ROI with Manufacturing Execution Systems*. Industry Directions Inc. . Retrieved on 18 August 2006 from <http://www.industrydirections.com>

Fraser, J. 1997. MES Explained: A High Level Vision. MESA International – White Paper Number 6. MESA [Online]. Retrieved on 15 July 2006 from <http://mesa.org/mesawhitepapers>

Gack, G.A. 2006. Applying Six Sigma to Software Implementation Projects. Six Sigma Advantage Inc. [Online]. Retrieved on 5 October 2006 from <http://software.isixsigma.com/library/content/c04091b.asp?action=print>

Gerold, J. 2005. MES Deals a Winning Hand. *Automationworld.com* [Online]. Retrieved on 3 October 2006 from <http://www.automationworld.com/print.php?id=1109>

Gerold, J. 2006. Expert Advice for Next-Gen Manufacturing. *Automationworld.com* [Online]. Retrieved on 3 October 2006 from <http://www.automationworld.com/print.php?id=1975>

Gorbach, G. 2005. Why Is Plant Floor Different? 2005. *ARC INSIGHTS # 2005-48EC* [Online]. Retrieved on 19 September 2006 from <http://www.arcweb.com>

Gorbach, G. 2005. Demand for CPM/MES Reported Strong in ALL Key Regional Markets. 2005. *ARC INSIGHTS # 2005-55ECMDP* [Online]. Retrieved on 19 September 2006 from <http://www.arcweb.com>



Gould, L.S. 2006. MES: Will E-commerce Drive IT Into Auto? *Automotive Design and Production* [Online]. Retrieved on 4 October 2006 from [http://www.autofieldguide.com/articles/article\\_print.cfm](http://www.autofieldguide.com/articles/article_print.cfm)

Hadjimichael, B. 2004. Manufacturing Execution Systems Integration and Intelligence. Unpublished master's thesis. Montreal: McGill University. Pp.6-23

Hakanson, W.P. 1994. Manufacturing Execution Systems software making its way to the shop floor – case studies of MES usage at Compaq, Komag and Advanced Micro Devices among others. *Electronic News* [Online] April 1994. Retrieved on 3 October 2006 from [http://www.findarticles.com/p/articles/mi\\_mOEKF/is\\_n2010\\_v40/ai\\_15322808](http://www.findarticles.com/p/articles/mi_mOEKF/is_n2010_v40/ai_15322808)

Harrington, L. & Sullivan, F. 2004. A New Look to an Old Challenge: Successful Software Implementations. Whitepaper by Remedy Services, a BMC Software Company, California, USA. Retrieved on 9 August 2006 from <http://www.remedy.com>

Hoske, M.T. 2001. See Clearly into Plant-Floor Applications. *Control Engineering* [Online] January. Retrieved on 4 October 2006 from <http://www.manufacturing.net/ctl/index.asp?layout=articlePrint&articleID=CA180937>

*How a new-generation MES can drive flexible manufacturing.* 2006. Apriso Corporation. Retrieved on 25 November 2006 from <http://www.apriso.com>

*How to Choose a Manufacturing System*. 2005. Sage Accpac International Inc. Retrieved on 14 March 2006 from <http://www.sageaccpac.com>

Huang, C. 2002. Distributed manufacturing execution systems: A workflow perspective. *Journal of Intelligent Manufacturing*. 13, 485-497.

Jakovljevic, P.J. 2005. The Challenges of Intergrating Enterprise Resource Planning and Manufacturing Execution Systems. *Technology Evaluation Centres – ERP Research Centre* [Online] November. Retrieved on 4 October 2006 from <http://www.technologyevaluation.com/research/reseachHighlights/erp/2005/11/research.html>

Jakovljevic, P.J. 2005. What are Manufacturing Execution Systems? *Technology Evaluation Centres – ERP Research Centre* [Online] November. Retrieved on 4 October 2006 from <http://www.technologyevaluation.com/research/reseachHighlights/erp/2005/11/research.html>

Johnson, C. 2006. Don't Overlook Manufacturing Execution in Your Product Lifecycle Management Strategy. *Visiprise*. Retrieved on 16 August 2006 from <http://www.visiprise.com>

Kall, J. 1999. Manufacturing Execution Systems: Leveraging Data for Competitive Advantage – Part 1. *Quality Digest* [Online] August. Retrieved on 4 October 2006 from [http://www.qualitydigest.com/aug99/html/body\\_mes.html](http://www.qualitydigest.com/aug99/html/body_mes.html)

Kall, J. 1999. Manufacturing Execution Systems: Leveraging Data for Competitive Advantage – Part 2. *Quality Digest* [Online] September. Retrieved on 4 October 2006 from [http://www.qualitydigest.com/sep99/html/body\\_mes2.html](http://www.qualitydigest.com/sep99/html/body_mes2.html)

Knight, J. & Lamb, S. 2006. Selecting and Using a Manufacturing Execution System. *Medical Device Link* [Online]. Retrieved on 4 October 2006 from <http://www.devicelink.com/grabber.php3?URL=http://www.devicelink.com/mddi/archive>

Kumar, S. 2005. Integrating MES and Enterprise Systems. *Infosys* [Online]. Retrieved on 2 October 2006 from <http://www.infosys.com>

Le Plastrier, M. 2002. Life, the universe and MES. *SA Instrumentation & Control* [Online] December. Retrieved on 5 October 2006 from <http://instrumentation.co.za/article.aspx?pk1Articleid=2162&pk1IssueID=297>

Le Plastrier, M. 2004. MES – is the tail wagging the dog? *SA Instrumentation & Control* [Online] June. Retrieved on 5 October 2006 from <http://instrumentation.co.za/article.aspx?pk1Articleid=3050&pk1IssueID=416>

Liker, J.K. 2004. *The Toyota Way*. New York: McGraw-Hill.

Lubbe, S. and Klopper, R. 2005. *Introduction to Research Design: An Interdisciplinary Approach*. Durban: Dolphin Coast

Manufacturing Execution Systems – Bridging the Information Gap between Boardroom and Plant-floor. 26 July 2004. *Frost and Sullivan Press Release* [Online]. Retrieved on 3 October 2006 from <http://www.frost.com/prod/servlet/press-release-print.pag?docid=21765359>

Manufacturing Execution System in Metals. 2001. The ABB Group. Retrieved on 4 October 2006 from <http://www.abb.com/cawp/seapr035/978a5fdf959dabe4c1256ae3003cfc3c.aspx>

Manufacturing Execution Systems: MES Defined. 2005. Cimnet Inc [Online]. Retrieved on 3 October 2006 from [http://www.cimnetinc.com/manufacturing\\_execution\\_systems.html](http://www.cimnetinc.com/manufacturing_execution_systems.html)

Manufacturing Execution System (TexMES). Texcomp Technologies Ltd, Mumbai, India. Retrieved on 4 October 2006 from <http://www.texcomp.com/tex-cd/solutions/texmes.htm>

Manufacturing in the age of e-business – the role of MES. 2000. *SA Instrumentation & Control* [Online] November. Retrieved on 5 October 2006 from <http://instrumentation.co.za/article.aspx?pk1Articleid=476&pk1IssueID=113>

Marcus, R. 2006. Six things to consider before a major software implementation. *Wisconsin Technology Network* [Online] June. Retrieved on 5 October 2006 from <http://www.wistechnology.com/printarticle.php?id=2749>

McClellan, M. 1997. *Applying Manufacturing Execution Systems*. Vancouver, CRC Press

McClellan, M. 2004. The Collaborative Effect. *Intelligent Enterprise* [Online]. Retrieved on 3 October 2006 from <http://www.intelligententerprise.com/showArticle.jhtml?articleID=50500796>

McClellan, M. 2004. Execution Systems: The Heart of Intelligent Manufacturing. *Intelligent Enterprise* [Online]. Retrieved on 3 October 2006 from <http://www.intelligententerprise.com/showArticle.jhtml?articleID=21400431>

McClellan, M. 2005. *Introduction to Manufacturing Execution Systems*. Vancouver: Collaboration Synergies Inc. <http://www.cosyninc.com>

McDonough, B. 2006. MES Considerations: Considerations for Manufacturing Execution System Implementation. Wiptrac.com [Online] May. Retrieved on 4 October 2006 from <http://www.sbainc.com/WIPtrac/consider.html>

McDowell, M. 2005. Is MES the answer for competitiveness in industry? *SA Instrumentation & Control* [Online] June. Retrieved on 5 October 2006 from <http://instrumentation.co.za/article.aspx?pk1Articleid=3518&pk1IssueID=489>

MES promises significant ROI within six months. *SA Instrumentation & Control* [Online] July. Retrieved on 5 October 2006 from <http://instrumentation.co.za/article.aspx?pk1Articleid=3577&pk1IssueID=495>

Nones, N.M. 2004. Do Chinese Enterprises Really Need MES and WMS? *Technology Evaluation Centres – SCM Research Centre* [Online] December. Retrieved on 4 October 2006 from <http://www.technologyevaluation.com/research/researchHighlights/scm/2005/07/research.html>.

Ohno, T. 1988. *Toyota Production System – Beyond Large-Scale Production*. English Edition. Portland: Productivity Press.

Pearce, J.A. II & Robinson, R.B. Jnr. 2003. *Strategic Management, Formulation, Implementation and Control*. Eighth Edition. New York: McGraw-Hill Irwin.

Phadke, R. 2006. Leveraging Manufacturing Execution Systems for global visibility of shop floor data. White Paper by Pantini Computer Systems Ltd. MA, USA.

<http://www.pantini.com>

Pieterse, J.J. 2006. *Completing the MBA dissertation*. Fourth Edition. Port Elizabeth: Nelson Mandela Metropolitan University – Business School.

Pieterse, J.J. 2005. *Leaning the South African Way*. Port Elisabeth: Down Town.

Plant wide Information: Manufacturing Execution Systems for SMB. *Industry Directions, Executive Brief March 2005* [Online]. Retrieved on 18 September 2006 from

<http://www.industrydirections.com>

POMS Manufacturing Execution System in Polpharma – Implementation Study. Warsaw.

ATM S.A. Retrieved on 30 June 2006 from <http://www.atm.com.pl>

Promise Of Efficiency Improvements Through Greater Real-Time Data Accessibility Spurs Demand For Manufacturing Execution Systems. 9 August 2002. Frost and Sullivan Press Release [Online]. Retrieved on 3 October 2006 from

<http://www.frost.com/prod/servlet/press-release-print.pag?docid=KMEE-5CUKEA>

Purtell, C. 1993. Manufacturing Execution Software – Can your company afford it, or afford not to have it? *Manufacturing Marketplace*, September. pp. 90 - 103

Rastle, C. & Bauer, M. 2005. The MES Advantage. *ABjournal.com*. April. pp. 38-45.

Reilly, K. 2005. AMR Research Finds Global Manufacturing Execution System (MES) Market Revenue Crossed \$1B Marker in 2004. AMR Research Press 23 June 2005 [Online]. Retrieved on 19 September 2006 from <http://www.amrresearch.com/content/printversion.asp?pmillid=18406>

Ross, J.W. & Weill, P. 2002. Six IT Decisions Your IT People Shouldn't Make. *Harvard Business Review* [Online]. November. Retrieved on 16 August 2006 from <http://www.hbr.org>

Rudder, R. 2003. Real-Time Manufacturing Maximises Productivity. *Manufacturing Engineering* [Online] Dec 2003. Retrieved on 3 October 2006 from [http://www.findarticles.com/p/articles/mi\\_qa3618/is\\_200312/ai\\_n9316603](http://www.findarticles.com/p/articles/mi_qa3618/is_200312/ai_n9316603)

Russel, R. 2004. Manufacturing execution systems: moving to the next level – Special Report. *Pharmaceutical Technology* [Online] Jan 2004. Retrieved on 3 October 2006 from [http://www.findarticles.com/p/articles/mi\\_mOEEH/is\\_1\\_28/ai\\_112793834](http://www.findarticles.com/p/articles/mi_mOEEH/is_1_28/ai_112793834)



Saunders, M., Lewis, P., Thornhill, A. 2003. *Research Methods for Business Students*. 3<sup>rd</sup> Edition, Harlow: Pearson Education Limited.

Seeley, R.S. 1997. Manufacturing Execution Systems: Bridging the gap between MRP/ERP systems and shop-floor controllers. *Medical Device Link* [Online]. Retrieved on 4 October 2006 from <http://www.devicelink.com/grabber.php3?URL=http://ww.devicelink.com/mddi/archive>

Shen, W & Norrie, D.H. 1999. Agent Based Systems for Intelligent Manufacturing: A State-of-the-Art Survey. *Knowledge and Information Systems, an International Journal*, 1(2), pp. 129-156. Its HTML version is available at: <http://imsg.enme.ucalgary.ca/>

Slater, D. 2000. Talk to Your Plants. *CIO Magazine* [Online] March 15. Retrieved on 4 October 2006 from <http://www.cio.com>

Software Implementation Challenges and Solutions. Whitepaper by Intelera, Moncton, Canada. Retrieved on 3 October 2006 from <http://www.intelera.com>

Sparrow, N. 2005. MES can help manufacturers achieve reduced cycle times, zero-error production, and automated compliance management. *Medical Device Link* [Online].

Retrieved on 4 October 2006 from <http://www.devicelink.com/grabber.php3?URL=http://ww.devicelink.com/emdm/archive>

Stoddard, D. & Costello, M.C. 1993. *Safeway Manufacturing Division: The Manufacturing Control System (MCS) (A)*. Boston MA. Harvard Business School. Rev May 18, 1993. pp. 193-134,

Streamlining Shop Floor Operations using a Manufacturing Execution System. *Nexgen PRMS In Focus* [Online] Vol. 7, 1<sup>st</sup> quarter, 2003. Retrieved on 8 October 2006 from <http://www.nexgeninfo.com>

Swanton, B. & Smith, A. 2003. MES provides Long-Term Revenue and Market Benefits Beyond Easy-to Quantify Operational Cost Savings. AMR Research Report [Online] 30 July. Retrieved on 8 October 2006 from <http://www.amr.com>

Trebilcock, B. 2006. MES market heats up. *Modern Materials Handling* [Online] January. Retrieved on 4 October 2006 from <http://www.mmh.com/index.asp?layout=articlePrint&articleID=CA6369939>

Trebilcock, B. 2006. Manufacturing Execution Systems heat up. *Modern Materials Handling* [Online] August. Retrieved on 4 October 2006 from <http://www.mmh.com/index.asp?layout=articlePrint&articleID=CA6313999>

Turbit, N. 2005. ERP Implementation – The Traps. The PROJECT PERFECT White Paper Collection [Online] June. Retrieved on 7 September 2006 from <http://www.projectperfect.com.au>

Unger, K. 2006. MES Definition Work Continues. *Automationworld.com* [Online]. Retrieved on 3 October 2006 from <http://www.automationworld.com/print.php?id=1972>

Vinhais, J.A. 1998. Manufacturing Execution Systems: The One-Stop Information Source. *Quality Digest* [Online]. Retrieved on 4 October 2006 from <http://www.Qualitydigest.com/sept98/html/mes.html>

Vijayan, J. 2000. Manufacturing Execution Systems. *Computerworld* [Online] July. Retrieved on 22 August 2006 from <http://www.computerworld.com>

Weidemann, R. 2006. Metals Industry – Does mainstream MES fail to meet the requirements? *Mining & Manufacturing Systems Magazine* (MMSmag) [Online] July. Retrieved on 5 October 2006 from <http://www.mmsmag.co.za/print.aspx?id=291>

Wilhite, T. 2006. Engineers play critical role in software implementation and selection. *Plant Engineering Magazine* [Online] January. Retrieved on 5 October 2006 from <http://www.manufacturing.net/pe/index.asp?layout=articlePrint&ArticleID=CA63160>