Optimising operations effectiveness and capacity at a heavy engineering plant

By

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Permission to undertake study & non disclosure of mini dissertation.

DCD-DORBYL, Heavy Engineering Vereeniging has granted Alan Reid permission to undertake an internal study into optimising operations effectiveness and capacity and to submit a mini dissertation on the results of this study.

However, due to the nature of the study and the information contained therein, the contents of the mini dissertation may not be disclosed for a period of 5 years, from the date of this letter. Disclosure of the contents of the mini dissertation would result in a loss of competitive advantage for the company.

Yours Sincerely

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ABSTRACT

This study focuses on optimising operations effectiveness and capacity at a heavy engineering plant, namely Heavy Engineering Vereeniging, a division of DCD-DORBYL (Pty) Ltd. The implementation and adoption of technology was included in the investigation. The company operates from 2 premises in Vereeniging and Vanderbijlpark (Gauteng), and consists of 5 factory buildings.

A literature review was conducted to ascertain current industry best practises and technology implementation initiatives. This review included a discussion on the following aspects: Capacity and its utilisation, flexible technology and advanced manufacturing systems, technology in manufacturing, capacity expansion and scheduling, factory layouts, technology and capacity utilisation in a South African context, and finally future trends in capacity and technology at Heavy Engineering Vereeniging.

Data collection from within the organisation was done via the issuing of a questionnaire and conducting interviews with various management and supervision employees. The gathered data was analysed for employees' opinions on current utilisation of capacity and use of technology, as well as suggestions regarding improved working methods, factory layout and the implementation of new technology. The quantitative data was analysed using the Statistical Package for the Social Sciences software, with the provided descriptive statistical test results used for the identification of possible trends and further interpretation.

It was found that current capacities and equipment are being well utilised, but not to their optimal level. The well entrenched management information systems, measurement systems and operating procedures currently in use will aid to increase the level of utilisation of the available capacity and equipment. The implementation of technology and latest best practises within the operation will gain HEV a competitive edge, ensuring their future sustainability and market leadership. However, this implementation must be done with the input and buy in of the work force. The variances in perceptions and attitudes between the various job functions, discovered during the statistical analysis, must be taken into cognisance during any capacity optimisation or technology implementation initiative. Continued capital expenditure and the current drives in research and development need to be maintained to further ensure sustainability.

Various inefficiencies were identified and recommendations were made to improve the current operation's effectiveness and factory layout, primarily by decreasing operating inefficiencies.

The recommendations were made based on the results of the study and included the expenditure involved in their execution. Financially viable options, calculated using payback periods and net present values (NPV), included the purchase of phased array ultrasonic testing equipment, horizontal SAW for longitudinal flanges and a modular type furnace.

Other options, which could improve operations effectiveness, but not returning financially positive results, included the moving of the Hausler roll into the main fabrication workshop and the moving of the Sachems drills to alongside the lathes.

A number of new processes and initiatives were recommended, for which cost comparisons to current similar practices could not be performed. These included the full production implementation of the punch through tandem arc submerged arc welding for wind turbine tower manufacture, implementation of a customer interfacing and communication platform and internal communication display boards. Current practises regarding touch time measurements for welding and drilling were validated.

By undertaking these recommendations, it was felt that HEV would continue to be well positioned to capture the predicted ongoing growth in the mining market in which they currently operate, and to fully benefit from the future upturn in the energy market.

List of key terms:

Operations effectiveness, capacity utilisation, technology adoption and implementation, competitive advantage, productivity improvements.

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DCD	DCD-DORBYL (Pty) Ltd, an engineering company in South Africa, comprising 9 operating divisions
FCAW	Flux cored arc welding, a semi automated welding process using a continuous wire feed
HEV	Heavy Engineering Vereeniging, a Division of DCD-DORBYL (Pty) Ltd
SAW	Submerged arc welding, a machine welding methodology using a continuous wire feed and shielding flux
UT	Ultrasonic testing, a method of non destructive testing, using ultrasound to detect internal welding defects

CHAPTER 1: ORIENTATION AND PROBLEM STATEMENT

1.1 Introduction

During an earlier study various processes in the value chain of DCD-DORBYL, Heavy Engineering Vereeniging were plotted and analysed. During this analysis, various inefficiencies were identified and recommendations were made to improve the overall functioning of the organisation. A final year engineering student at the University of Pretoria conducted a research project in 2006 regarding the cost of transport between the various factory sites of Heavy Engineering Vereeniging (HEV) and the relocation of factory sites to one central location (Janse van Rensburg, 2006:7). Both of these studies, along with further literature review, are used as a basis for this research proposal.

Currently, the inefficiencies within the operation and cost associated to these inefficiencies are inherited from the nature of the company and the location of the operations. The company grew by acquisitions, which resulted in a company with operations which are geographically separated. The manufactured products usually have to pass through 3 of the 5 sites. Adding to this is their originally as-built work centre (or “jobbing shop”) layout. Pre-scientific investigations of the industry standard for this type of heavy engineering operation have shown the layout now more suited to the products manufactured is a process flow type layout (Jacobs, Chase & Aquilano, 2009; Hameri, 2010:233-241).

Traditional methods and processes of working are still evident – the adoption of technology has usually met with resistance to change, usually due to unfamiliarity with and uncertainty as to the new process and fear of job reductions (Coetzee & Engelbrecht, 2011). The uncertainty of the new process is coupled with the fear of non successful implementation and blame apportionment should the new process be a failure or cause non conformances on the work piece. This can be overcome by trial implementation of the new process, either on a test basis within the factory or, preferably, at the supplier. Another factor discussed was ‘non business owner’ attitudes of various employees, where the gains obtained from productivity initiatives are irrelevant to the affected employees, where comfort with current operating methods is preferred (Coetzee & Engelbrecht, 2011).

1.2 Background to the study (motivation)

This research proposal addresses improving the current operation’s effectiveness and capacity at the Heavy Engineering Vereeniging Works, one of 9 divisions within the DCD-DORBYL group of companies. Included in the scope is the increasing of capacity to cope with future upturns in the current market and the expected increase in workload from the expected upturns. Additional opportunities are also expected to realize from new identified markets.

This division produces mining, materials handling and other associated metallurgical equipment. This equipment is used in the gold, platinum, copper, iron ore, diamond and coal mining industries. Other products include equipment for electrical power generation and petrochemical equipment.

Of the total Heavy Engineering Vereeniging (HEV) works turnover, 70 % results from the sale of grinding mill shells. The remainder of turnover comprises the sale of gyratory crushers (14%), dragline components (7%), with mine winders, kilns, materials handling and petrochemical equipment forming the balance (9%) (Colegate, 2010).

Of all products produced, 83% are exported, to South America, the USA, Canada, Australia, Europe, Scandinavia, Africa, the Middle and Far East. The remaining 17 % is for the South African market (Colegate, 2010).

Description of the Operations of HEV: Operations are found on 2 sites – the first site consists of 4 factory buildings in Duncanville, Vereeniging and the second site of 1 factory building in Vanderbijlpark. The composition of each site, separated by 25 km, is as follows:

<u>Vereeniging:</u> 4 factory buildings consisting of:

- 4 fabrication bays at south works
- fabrication bays at north works
- 1 roll shop bay at south works
- 4 machine shop bays at north works

<u>Vanderbijlpark:</u> 1 factory building consisting of 2 machine shop bays.

It is perceived various actions can be implemented to improve the effectiveness of these dispersed operations, increase the overall works efficiency and ultimately grow the capacity of the organisation. All recommendations will be based on sound financial analysis.

1.3 Problem statement

The factory facilities at HEV were originally built around a work centre (jobbing shop) environment. Various sites that used to operate as separate companies now operate as the same entity, after company acquisitions and mergers of operations. This has lead to a fragmented operation, operating off multiple sites, and has led to various operating inefficiencies. Included in the inefficiencies are old work methods still in use and possibly due to resistance to change from employees who have operated in this environment for many years. The average age of staff employees is 48 years, with average company service of 19 years. The average age of hourly paid (waged) employees is 42 years, with average company service for hourly paid employees being 14 years (Steyn, 2011). The increase in size of products also seems to have outgrown the original design and layout of the available workspace and infrastructure. Recent world economic upturns in 2007 and 2008 proved current capacities were inadequate. During this period, turnover grew from a base of R 164.7 million at financial year ending March 2007 to R 442.6 million at financial year ending March 2009; an increase of 269 % (Colegate, 2010)

The ideal operating state is a single operating location, using the latest production methodologies and technologies, operating in a process flow factory layout (Hameri, 2010:233-241). It is therefore evident that a gap exists, between the current facility and the industry recognized best practice.

1.4 Objectives of the study

Primary and secondary objectives are as detailed below:

1.4.1 Primary objectives

The primary objective is to make recommendations to improve the current operation's effectiveness and factory layout, primarily by decreasing operating inefficiencies. This will include establishing the financial benefit of the introduction of technology and improved methods of manufacture to replace old work methods and the rearranging of old work flows.

The effect of this recommendation may be measured by the theoretical decrease in manufacturing cycle times, reduction of hours used, and improved profits and delivery times.

Fulfilling these objectives will allow HEV to cope with future upturns in the market and the increase in workload from the upturn. The upturn in workload may also result from lower pricing structures of the products, resulting from the meeting of these objectives. Employee motivation and satisfaction will also be enhanced with their involvement in the change processes.

1.4.2 Secondary objectives

Secondary objectives will include:

(a) To calculate the cost resulting from inefficiencies in the production systems. This could include logistics costs, factory setup costs, opportunity costs and cost of poor quality

(b) to propose changes to the present mode of operation and processes, and

(c) to carry out a cost-benefit analysis of the proposed changes

1.5 Scope of the study

This study will focus on the operating effectiveness of the current operations of the HEV works of DCD-DORBYL, situated on 2 sites in Vereeniging and Vanderbijlpark. This organisation falls within the manufacturing industry, with focus on the manufacture of heavy mining and materials handling equipment.

The study will focus on inefficiencies already identified in previous studies as well as additional inefficiencies that were observed during this study, and their reduction. The financial viability, pay back period and net present value (NPV) for the expenditure involved in their execution will be discussed.

The recommendations may include:

- Process flow, equipment locations and layout changes within the fabrication shop and Vereeniging machine shop.
- Location and size of the largest stress relieving furnace, currently in Vanderbijlpark.
- Relocation of one of the two sites, consolidating all operations to one facility.
- Splitting of product lines, such that the 2 sites can operate independently of each other.
- Implementation of replacement new technology for work processes.

1.6 Research methodology

1.6.1 Literature / theoretical study (content and sources of references)

Two previous studies were used as a start point for this research project:

- A study in which the various processes in the value chain of DCD-DORBYL, Heavy Engineering Vereeniging were plotted and analysed. During this analysis, various inefficiencies were identified and recommendations were made to improve the overall functioning of the organisation.
- The research project titled "The analysis and integration of the manufacturing process for Heavy Engineering Vereeniging, a Division of DCD-DORBYL" (Janse van Rensburg, 2006).

Both of these studies, along with further literature review, were used as a basis for this mini dissertation. The extensive literature search and review will include previous similar projects conducted in the manufacturing industry, both internationally and locally, and current trends and methods utilized in this industry. Sources to be consulted will include library resources such as (but not limited to) EBSCOHost and ScienceDirect.

1.6.2 Empirical study

This will include data collection and review of current manufacturing methods and technologies used within this manufacturing environment. Touch times and their trends, such as those for welding and drilling, will be analysed to assess the impact of current and future initiatives.

Questionnaires and interviews with employees regarding suggestions for improved working methods, factory layout and implementing new technology may be utilised to gather information. This will also reflect sources of workplace ergonomic dissatisfaction, which may in turn lead to inefficiencies.

The study will include the financial analysis and viability of returns on investment associated with the implementation of each of the recommendations. Measures of net present value, internal rates of return and payback periods will be utilised to determine the attractiveness of the recommended changes.

1.7 Limitations of the study

The possible lack of information and previous studies done on a similar heavy engineering manufacturing company, having to operate from multiple locations and having outgrown its current facilities, due to current manufactured item size requirements and the change in the suitability of the factory layout. Limitations include time constrains in issuing a questionnaire to the complete target population of all employees at HEV.

1.8 Layout of the study

The chapter layout of this study will follow a similar structure to the orientation described above.

The chapters are as follows:

Chapter 1: As detailed in this chapter, the nature and scope of this study.

Chapter 2: Literature study on best practices and technology used in this industry.

Chapter 3: Research design and methodology. Included is a discussion on the instruments used in the measurement of the key variables, details on data collection methods and the analysis of the data. Data shortcomings and sources of error are also discussed.

Chapter 4: The results of the fieldwork are documented and discussed in this chapter. Included is their presentation and interpretation.

Chapter 5: Conclusions and recommendations, including possible options for improvement and their associated calculations for the financial analysis. This is done with the literature and theory review in mind, significance of the results reviewed, with gaps, anomalies and deviations in the data discussed.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter a review of the literature was conducted. In an effort to keep the study as recent as possible, as far as practical, only articles from 2005 were reviewed and included in the discussion below.

The literature review includes a discussion on the following aspects: Capacity and its utilisation, flexible technology and advanced manufacturing systems, technology in manufacturing, capacity expansion and scheduling, factory layouts, technology and capacity utilisation in a South African context, and finally future trends in capacity and technology at Heavy Engineering Vereeniging.

2.2 Capacity and its utilisation

In their study of manufacturing in the United States , Ray, Mukherjee and Wu (2005:526-548) found there is an overall downward trend of capacity utilization in total manufacturing, however there have been rises and falls in capacity utilization consistent with the expansions and contractions of the overall economy. This same study found capacity utilization to be higher than 90 %, indicating that increases in output would not have been possible by merely reallocating the variable inputs of a manufacturing system, given a fixed budget constraint. They found the budget constraint for increased input or increased capital expenditure was higher during times of high inflation and was more binding for the primary metals, fabricated metals, electrical and electronic equipment and industrial and commercial machinery sectors (Ray, Mukherjee & Wu, 2005:526-548).

Bansak, Morin & Starr (2007:631-645) examined the relationships between capacity utilization, capital spending, and technological change. They confirmed that firms may change their utilization of existing capacity, change the level of capacity using existing technology, or change capacity and technology at the same time. For a given current and future expected increase in demand, a firm may then:

(a) change output without changing capacity:

This excludes the installation of new capacity or reducing excess capacity, but rather more fully utilising existing capacity. This allows for a company to respond quickly to changes in demand. The negative implications are that running at a high rate of utilization continuously may raise unit costs while running at a low rate continuously wastes excess capacity. Operating in this mode, utilisation follows demand closely.

(b) change output and change capacity, using existing technology

This involves the adjustment of capacity by increasing fixed costs, such as for the purchase of capital equipment. Resources may be diverted until the new capacity becomes available, which may temporarily decrease output. In the long run, a higher level of output is achieved without costs rising.

(c) change output and change capacity, using new technology.

This is similar to the previous strategy discussed above, but involves a change in technique. It is associated with increased fixed costs (by the purchase of new technologies and equipment) with short run decreases in output until the new technology becomes available for production. However, the new technology provides an opportunity to reduce unit costs, thereby increasing profitability.

Management of capacity is given a degree of flexibility by modern manufacturing methods. Computer numerically controlled (CNC) machines, programmable controllers and modular assemblies allow for the easy adjustment of the composition and level of output. Modular tooling and computer aided and automated design lowers the overall cost and time needed to expand capacity (Bansak *et al*, 2007:631-645).

The expected profitability from each of the 3 change strategies above will determine which strategy is followed (Bansak *et al*, 2007:631-645).

This study found that technological changes negatively affect utilization levels and the level of investment. Given the increase in flexible manufacturing that the implementation of technology offers, firms prefer holding excess capacity to cope with upswings in demand. Excess capacity allows for a firm to produce additional output without stretching resources and moving into the steeply sloped portion of the marginal cost curve, as would happen if the firm was already operating close to its' limit of capacity. The implementation of this strategy became evident in the second half of the 1990's, when manufacturing output increased, without a significant increase in unit costs and associated inflation (Bansak *et al*, 2007:631-645). However, it is found that inflation begins to increase when capacity utilisation continuously exceeds 82 percent (Corrado & Mattey, 1997:151-167). This would also be true for individual firms, who would begin to charge a premium for their goods if they operate at high levels of capacity, due to higher levels of demand.

As high technology capital becomes less expensive, the holding of excess capacity too becomes less expensive. However, it was found with an increase in the use of technology, the average industry decrease in utilisation from 1974 to 2000 was in the range of 0.2 to 2.3 percent only (Bansak *et al*, 2007:631-645).

In the United States, the Federal Reserve uses the following formula to measure the utilisation of capacity:

U = IP/ICAP, where:

U is a utilisation rate obtained from a yearly survey, taken at the end of the year. Respondents to the survey estimate their capacity utilisation rates, given their current sustainable output versus their peak output level, based on hours worked by production workers. There is also a check list to complete if the operation's capacity has increased over the last year. ICAP is an Industrial Capacity index at the end of a year, while IP is an Industrial Production index at the end of a year. Solving for one of the unknowns in the equation gives the individual company an indication of how they compare to the industry norm of yearly published figures for manufacturing firms in the USA (Whitney, 2003:52).

Utilisation of capacity to deal with changes in demand depends on the type of functioning of the operation. Three types were identified by Corrado & Mattey (1997:151-167); these being pure assembly line operations, work station operations and continuous processor operations.

Assembly line operations vary the normal work periods of the plant to accommodate additional output. This includes extending shifts by working overtime, adding additional shifts or changing the speed of the total process. Focusing on bottlenecks and reducing their effect will increase output. In work station operations, additional output is added by the addition of additional shifts or extending shifts at the individual workstations, or by creating new workstations. For both of the above 2 processes, start up and shut down costs are relatively small.

Continuous processors face large start up and shut down costs, such that these plants are normally run continuously, i.e. 24 hours a day, 7 days a week. Examples are oil refineries, paper mills and steel manufacturing mills. Shut downs are normally planned well in advance and last for an extended duration (Corrado & Mattey, 1997:151-167). Changes in output are achieved by changing the rate of consumption of raw materials, or input of raw materials. Additional output would typically be held in stock, as the production process and output cannot be easily altered to accommodate large fluctuations in demand.

In a made to stock (MTS) manufacturing operation, 2 theories of coping with fluctuations in demand exist (Erol, 1999:21). The uncertainty imposed on management due to the difficult to predict demand fluctuations can be dealt with by:

- Locking in regular production, such that there is a deficit of product in times of high demand (and the associated lost opportunities), and a surplus of product in times of lower demand (such that surplus product is stored in stock).
- Adapt resources and capacities to continually and instantly alter to the fluctuations in demand, such that perfect reactivity to demand is created.

Both of the above strategies have their advantages and disadvantages, and it was found that a compromise between the 2 extremes is usually the best policy and the one adopted by MTS manufacturers to optimise resources to meet demand fluctuations (Erol, 1999:21).

Made to order (MTO) operations usually also adopt a similar hybrid approach (Chen, Mestry, Damodaran & Wang, 2009:1461-1473). For its core competency, a MTO operation maintains a certain level of production capacity. However, as every order is a back order and requires customisation to customer specifications and design, a MTO operation cannot rely on inventory to leverage fluctuations in demand. Demand fluctuations are then dealt with using overtime, additional shifts and subcontracting to adjust capacity.

A MTO operation only commences work on an order after the order is placed. Potential orders are evaluated on the following four questions:

(1) Do they have the technical capability to handle the order?
(2) Do they have the production capacity to accommodate the order?
(3) Can they complete the order in time for delivery?
(4) How much is the profit from the order? (Chen *et al*, 2009:1461-1473)

2.3 Flexible technology and advanced manufacturing systems:

In their paper, Rezaie and Ostadi (2006:729-736) discussed the concern regarding the deterioration of manufacturing competitiveness. They proposed that a flexible manufacturing system (FMS) will aid in regaining the competitive edge. This is done via improvements in productivity and quality, as well as the company's ability to adapt effectively to changing circumstances, such as demand, and the vulnerabilities due to fluctuating demand, variations in product mix and further improvements in technology in production. They found the implementation of flexible technologies followed 3 steps:

(1) Investment appraisal – identification of areas that require flexible technology and the profitability of the investment
(2) Selection of technology – deciding on the best and most cost effective technology to implement, after the evaluation of alternatives
(3) Technical installation – installation of the selected technology.

Various programming models exist for the optimal and phased implementation of flexible technology in a manufacturing system. Various of the models are able to accommodate for learning effects and non-linearities (e.g. setup costs, economies of scale and congestions) (Rezaie & Ostadi, 2006:729-736).

Their study further confirmed that flexible technology can be implemented via evolutionary or radical methods. Radical methods involve the less frequent but large additions of technology. This however can be economically unviable for small and medium sized companies, due to the initial financial outlay required. Evolutionary methods involve smaller but more frequent additions of technology and would be more economically viable for smaller companies. Evolutionary acquisitions include the added benefit of a steady state of learning for the company, allowing for a more successful implementation of flexible technology (Rezaie & Ostadi, 2006:729-736).

Agile manufacturing is described as the new and revolutionary next step in manufacturing and assembling products (Hormozi, 2001:132-143). It follows its predecessors of craft production, mass production, and lean (Just In Time or JIT) production. Agility is the ability to embrace change and adapt quickly. Agility of a business is needed to ensure the traditional manufacturing organisation is able to keep pace with the ever increasing rate of change observed in the business environment. A lack of agility results in a business losing opportunities, which may eventually lead to the demise of the business. Efficient reconfiguration of operations, processes and business relationships in an ever changing environment are essential.

In this study, it was found the successful implementation of an agile manufacturing system requires changes in 5 areas: government regulation, business cooperation, information technology, re-engineering and employee flexibility. Cooperation between the Government and businesses is seen as crucial, along with the requirement of a strong infrastructure (Hormozi, 2001:132-143)

Business cooperation includes companies in the total value adding chain working together to improve manufacturing, incorporating design, selling, manufacturing and distribution aspects. Flexibility and creativity from employees is also required for agile manufacturing implementation, where the needs of the customer are addressed first and foremost. Allowance for customisation is key (Hormozi, 2001:132-143).

Improving the efficiency in technology in a company is important to stay competitive (Teng & Seetharaman, 2003:490-496). Advanced Manufacturing Technology (AMT) involves new manufacturing techniques and machines, and includes the incorporation of information technology, microelectronics and new organisational practices. Their study found the following top reasons companies implement AMT, in order of importance:

(1) Improving product quality and reliability
(2) Reducing production costs
(3) Reducing manufacturing lead times
(4) Reducing scrap and rework
(5) Increasing labour productivity

Problems listed with the installation of AMT included, in decreasing order:

(1) Integrating automatic and manual operation, including unforeseen interface problems
(2) Justifying investment in AMT
(3) Interfacing hardware and software
(4) Developing AMT software
(5) Encouraging cross functional teamwork activity on the AMT projects
(6) Installing and pre-installing support from the AMT vendors and outside consultants.

(Teng & Seetharaman, 2003:490-496)

Introducing new technologies (AMT) also changes the level of skill and qualifications needed by personnel. Training is seen as the most important tool in guaranteeing the full potential of the new manufacturing process innovation is realised, as it is critical for both human and the physical resources to work together. Very often, the human aspect of AMT is ignored, with a company's strategy focusing on the investment in physical capital resources only. Another factor that tends to detract from personnel training is the possibility of trained employees leaving the service of the company. As the direct training costs cannot be recovered, labour rate turnovers have an effect on company training efforts (Castrillon & Cantorna, 2004:268-280).

2.4 Technology in manufacturing

Davis & Venkatesh (2000:14) described having a strategy for the implementation of technology with regard to employee acceptance as vital. Employees were more likely to accept and use a new technology if it was directly useful to their jobs and performed the required tasks well, increasing employee productivity. A demonstration of results was the best option and could be used as a comparison to old productivity levels, before the new technology was implemented (Davis & Venkatesh, 2000:14).

Examples of employee acceptance using new technologies have been evident at HEV in the past. In the early 1990's, flux cored arc welding (FCAW) replaced shielded metal arc welding (SMAW) and gas metal arc welding (GMAW), due to its high weld metal deposition rate. Welders initially resisted this change to a new technology, however readily accepted it when its ease of use and higher quality welds produced became evident. A similar acceptance of Tandem Submerged Arc Welding was experienced in 2002, when this new method of producing automated welds was introduced. Higher deposition rates and increase of welding output were the main drivers for new this new method’s acceptance (Putter, 2011).

Another important aspect of new technology is internal and external customer communication technologies. Communication tools already well established include telephone, e-mail, web page contact forms, self help frequently asked questions and In-house software. The latest trend is instant messaging, known as chat (Kenny, 2008:60). Furthermore, not only must these customer interface technologies be used for communication, but they should also quantitatively be used to measure how much satisfaction is experienced by customers (Kenny, 2008:60).

The danger of instant messaging tools (such as Google Talk, Yahoo! Messenger, Microsoft Live Messenger and Skype Messenger) is they are not secure, making it advisable to not communicate sensitive information via this medium (Salesguru, 2009)

Facebook, Linked-In and Skype are further networking tools that may be used to communicate with customers or employees, and for making new customer contacts via the “friend” network on Facebook (Rumford, 2007). However, as both Skype and Facebook are used extensively as social networking sites, most large corporations have banned their use during company working hours, which may prove them to be ineffectual as customer interfacing tools.

2.5 Capacity expansion and scheduling

Delivery time guarantees can be used to give a competitive advantage, both in a service and a manufacturing industry, where price and delivery times are both important. Investment decisions for capacity expansion can be based on the importance of delivery reliability and increasing the probability of delivering on the guaranteed delivery time (So & Song, 1998:28-49).

Capacity and project scheduling software programs are available, for example Primavera 6.0 (P6). This software offers an organisation advanced project management and scheduling capabilities, such as what-if scenario modelling, portfolio analysis, capacity analysis, scorecards, rich graphics and optimization functionality. From a single database, an organisation is able to plan, execute and control thousands of projects. As a web based application, project reporting to customers is facilitated, and customers can be presented with a range of outcomes for a portfolio of their projects. This enables customers to mitigate their delivery risks by providing input as to their preferred delivery schedules (M2PressWire, 2007).

MS Projects was used as a scheduling tool at HEV, however HEV has recently installed Preactor 500 APS, another form of scheduling program, with full implementation scheduled for end August 2011. Preactor has the ability to schedule the constraints and bottlenecks with a production order system, taking delivery dates into account (Noeth, 2011).

While sophisticated algorithms exist for capacity planning and production optimisation, it has been found that production planners often use less sophisticated planning methods than those available, and achieve more satisfaction and intuitive results than produced by the complex algorithm programs (Tenhiala, 2010:65-77).

In this same study, it was noted that different planning methods are better suited to different types of manufacturing operations. In make-to-order (MTO) manufacturing, time-phased planning is important, while JIT methods are optimal in make-to-stock environments. Forcing JIT methods onto MTO manufacturing does not eliminate the complexity of producing to individual orders, as customisation in MTO is essential. JIT can be used upstream of the split of the product into a customised item (Tenhiala, 2010:65-77).

2.6 Factory layouts

In the research presented by Hameri (2010:233-241), Production Flow Analysis (PFA) is described as a methodology used for transforming functional factory layouts to product oriented layouts. Natural clusters of workstations are found that can perform production cell operations, simplifying the material flow through the workshop. Scheduling is then simplified to a period batch control where fixed planning, production and delivery cycles are established for the whole production unit, and can free up capacity and scheduling administration. PFA can be applied to job shops (work centre factories) with functional layouts, converting them to manufacturing groups, with the aim of reducing lead times and bottlenecks, improving quality and employee motivation (Hameri, 2010:233-241).

There are challenges in creating practical groupings for product manufacturing, particularly in a job shop environment with high product varieties and low volumes. However, the view is taken that a process oriented layout may still be the best option for some job shops, and is supported in evidence that most job shops have process oriented layouts, versus cellular or continuous flow layouts (Hameri, 2010:233-241).

2.7 <u>In a South African context</u>

South Africa has a developing economy, but displays characteristics found in developed countries. This dual world status and political history provide a unique set of challenges, adding burden to South African managers. Some of these challenges to be addressed in the formulation of a technology policy include: affirmative action, employment equity, employee empowerment, relationships between various stakeholders, political changes and a new business climate (both local and international) (Hipkin, 2004:245-260).

Product complexity (for value maximisation) and process complexity (for cost minimisation) factors have to be addressed and balanced in a technology policy. Technologies chosen will be restricted by resources, competencies and financial constraints (Hipkin, 2004:245-260), however the implementation of new technologies is vital to ensure an expansion of the export base.

Four levels in technological capabilities were found: (1) assembly or turnkey operations, (2) adaptation and localization of components, (3) product redesign, and (4) independent design of products. Developing countries usually operate on levels (1) and (2), however it is important for developing countries to move to levels (3) and (4) to ensure they can obtain first mover advantage and can then compete internationally with developed economies. In this same study, it was found automation does not necessarily lead to more effective manufacturing – this as higher levels of know how are required for greater adherence to set procedures and increased levels of machine complexity (Hipkin, 2004:245-260).

South Africa has its own set of challenges for conducting business. From the Global Competitiveness Report for 2008, of a total of 133 countries surveyed, South Africa ranked poorly in the following categories: organised crime (119), quality of primary education (107), quality of maths and science education (133), quality of education system (119), internet access in schools (100), tertiary enrolment (94), hiring and firing practices (125), pay and productivity (105), availability of scientists and engineers (123).

However, SA ranked highly in the following areas: strengths of auditing and reporting standards (2), protection of minority shareholder interests (9), financial market sophistication (6), legal rights interest (5), soundness of banks (6) (Herrinton, Kew & Kew, 2009:1-173).

138 South African managers, whom were participating in management development programs at the University of Cape Town in 2000 and 2001, were asked for their perceptions regarding the importance in determining the technology policy in a manufacturing environment. These managers worked in the construction, consumer goods manufacture, heavy manufacturing, mining, motor and utilities sectors. The most important factors found in the management of technology in SA are listed below, along with their findings and implications (Hipkin, 2004:245-260):

2.7.1 Economic and political

Listed factors were crime levels in South Africa, the brain drain (skilled people leaving the country), affirmative action and employment equity policies, low educational levels of labour.

While economical and political factors scored highest in importance, managers have little control over them. Technological strategy was not greatly affected by this factor, however the poor education system will fail to provide the technically qualified workforce. Union relations are often difficult.

2.7.2 Human resources

Listed factors were increasing shortages of skilled personnel, Aids, empowerment, commitment to on-going training.

Aids and poor education affect operational rather than strategic policies. Training in new technology and the related skills development is essential to gain the advantage for operations and strategy, leading to competitive advantage. Affirmative action policies must create a learning organisation.

2.7.3 Technical issues

Listed factors were short lead time for spares, greater output through new technology, adaptability of technology to local conditions, robustness of new technology, higher quality through new technology, transfer of core technology to acquirer, overall level of economic development and infrastructure.

Quality and output improvements are achievable through technology, however the technology implemented must be robust to overcome infrastructure and training difficulties. The correct interfacing between human and technical resources is essential for the gain of maximum benefit from technology implementation.

2.7.4 Operational and financial issues

Listed factors were change management, internal infrastructure to accommodate new technology, revisit maintenance management, quantification of hidden costs of technology, transfer of physical equipment and systems, justification of technology on a cost / benefit basis, promoters / champions for new technology implementation, clear objectives required from technology, cost a major factor when selecting new technology.

A poorly educated workforce detracts from realising the full benefits of new technology. Difficulties in the implementation of new technologies (including their integration with systems and resources) often result in the failure of meeting the technology strategies. While cost is a major factor in selecting technology, cost versus benefit analysis are not performed, as benefits are often difficult to quantify.

2.7.5 Knowledge

This includes the diffusion of intangible knowledge, codification and documentation of knowledge related to technology, understanding new technology, development of communications and IT systems, and the creation of knowledge-based / learning organisations.

It was found the learning organisation and tacit knowledge are not often understood. Training provides the only mechanism for diffusing knowledge and understanding of technology - until this is done, lack of knowledge results in difficulties experienced in the operating of new equipment.

2.7.6 Shorter-term strategy

Included is the alignment of business goals, systems and technology, distinctive competency from technology, technology to provide first-mover advantage, technology to support knowledge-based business aims, strategic alliances (JV, FDI, licence) and new relationships with stakeholders.

International competition is forcing SA companies to obtain technology to close the technological deficit gap, compared to other global companies. It was found SA companies do partially align their business goals with technology, however co-ordination at a strategic level is essential. First mover advantage is lost if advanced technology is not implemented.

2.7.7 Technology partnerships

Factors included the establishment of an appropriate technology base from partnerships, changing approach to supply chain management, operational compatibility between owner and acquirer, supplier networks, management of contractual arrangements, Government regulations and bureaucracy and cost of developing workforce with technology suppliers.

In comparison to large United States companies, SA companies do not use supply chains and networks extensively. Partnerships and procurement from Broad Based Black Economic Empowerment (BBBEE) companies is part of government policy, however the emphasis should be on technology transfer and the formation of close relationships, especially with BBBEE companies.

2.7.8 Longer-term strategy

The longer term strategy should include technology to provide an intangible resource base, technology to shift from a product to a process base, technology to neutralise advantages of competitors and revisiting vertical integration.

It was found SA companies used technology to meet immediate operational requirements, and did not view technology as a long term strategic competency. The current non importance of technology as a core competence will be required to change to ensure long run sustainability of SA companies.

2.7.9 Culture

It was determined the acquiring firm's culture is important in selecting a particular technology, the acquirer's national culture is important in setting a technology policy, a dependency culture relies excessively on imported technology, there are limits to proceduralisation of activities through technology and there is an underlying resistance to imported technology.

It was noted that cultural aspects were not deemed important in an adoption of a technology strategy.

Further to a South African context, deficiencies were found in the implementation of technology at a large steel making company (Bester, 1997). These included:

- Strong functional organisational structures resulted in a lack of inter departmental communication.
- Lack of a defined technology strategy or the communication to all levels of the technology strategy.
- Lack of detail during the exchange of information between the supplier of technology and the user of the new technology.
- Technology implemented does not fit local (South African) conditions.
- The technology supplier's knowledge base is not known, i.e. there is a lack of confidence in the supplier's experience in the industry
- Non quantification or communication of the technology users' level of acceptable risk taking.

2.8 <u>Future trends in capacity and technology at Heavy Engineering Vereeniging</u>

HEV has identified the energy sector as a market in which to expand. The Integrated Resource Plan (IRP) 2010 for electricity details the increase in electrical generation capacity and the mix of electricity generation in South Africa until 2030. Included in the increase in electrical generation capacity, from the current levels of 45 Giga Watts to 89 Giga Watts in 2030, is an additional 9,600 Mega Watts of new nuclear power and 8,400 Mega Watts of wind generation capacity (Creamer, 2011:1).

The additional wind and nuclear energy new build power plants have been identified by HEV as areas to be targeted for future growth and sustainability. These markets will provide a diversified revenue stream and decrease reliance on the current mining market segment. The mining market has shown its sensitivity to world commodity demand, which dramatically decreased on the back of the recent global recession. HEV's current strength in the mining industry can be used as a springboard for the financing of the move into the energy sector. This will allow HEV to sustain its competitive advantage over its current competitors, and emerge as a market leader in the energy sector. Previously and currently manufactured energy sector components can be used as a marketing tool to move further into manufacturing for the energy sector. Competition within the mining sector is expected to remain stable, however the competition levels within the energy sector are expected to increase as the South African Government moves closer to final approval and implementation of the IRP 2010 (Booyse *et al*, 2011)

By entering the nuclear manufacturing market, opportunities for technology transfer exist. With a small amount of technology transfer and knowledge sharing, the balance of plant items for a power station can be manufactured by HEV. With in depth technology transfer, knowledge sharing and partnership with the nuclear technology holder, nuclear components and pressure components can be built.

Opportunities in the wind energy sector would provide the viability to erect a dedicated wind tower manufacturing production line, utilising the latest available production methods and equipment (Booyse *et al*, 2011).

Efforts to establish a unique product, for which HEV owns the design and is the exclusive manufacturer, are to be pursued. The newly established research and development department should make this a priority, along with efforts in optimising the fabrication of traditionally cast items (such as fabricated gears and mill trunnions) and providing best cost solutions for customer's products (Booyse *et al*, 2011).

Other current drives include (Booyse *et al*, 2011):

(1) Capacity expansion by capital expenditure
(2) Marketing drives in branding - including exposure to the final end users of products, as it was established they have a say in the placement of orders originating from HEV's customers – the original equipment manufacturers (OEM's).
(3) Using to full advantage HEV's BBBEE status – this is especially important when dealing with Eskom, the South African Government and their localisation policies.
(4) Environmental management certification, such as ISO 14000

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction & Research Methodology

This chapter sets the background for the research design, defining the research problem, collection of primary data (via a questionnaire) and secondary data, detailing the design of the questionnaire used in the field study, data collection methodology and processing of the results. A discussion of the results is conducted in chapter 4, with conclusions and recommendations following in chapter 5.

The research design details the plan of how to conduct the research. Research involves the systematic collection, analysis and interpretation of data, in a controlled manner, using objective methods and procedures. It also identifies current gaps in knowledge and verifies that which is already known. Identification of past errors and limitations is also possible via conducting research (Mouton, 2011:49).

A structured questionnaire was used in the field study for the gathering of primary data. A description of the questionnaire is given in this chapter, where questions were formulated to research the problem statement given in chapter 1, and to validate the findings of the literature review, conducted in chapter 2. The questionnaire, found in appendix A, included input from internal experts and the personal experience of the author.

A vast number of methods exist for gathering data. Mouton (2011:107) describes two of these - qualitative methods and quantitative methods.

The methods used in this mini dissertation include both qualitative and quantitative methods. Statistics were used to describe and analyse the quantitative data gathered.

Qualitative methods were included such that participants in the questionnaire had an opportunity to provide insight into aspects that were not addressed by the rigid quantitative measurements on the questionnaire. This allowed for a degree of freedom, ensuring good suggestions for capacity optimization, utilization and technology implementation could be listed, such as is not provided for by a purely quantitative measure.

However, qualitative methods must allow for a degree of interpretation, and careful analysis of the given answers must be undertaken to ensure there is no misinterpretation or misrepresentation of the answers provided.

3.2 Defining the research problem - hypothesis, conceptualisation, definitions and key variables

The primary objective of this mini dissertation is to make recommendations to improve the current operation's effectiveness and factory layout, primarily by decreasing operating inefficiencies. This will include establishing the financial benefit of the introduction of technology and improved methods of manufacture to replace old work methods and the rearranging of old work flows.

The effect of this recommendation may be measured by the theoretical decrease in manufacturing cycle times, reduction of hours used, and improved profits and delivery times. This measurement is beyond the scope of this study and will be done after implementing any proposals forthcoming from this study.

Fulfilling these objectives will allow HEV to cope with future upturns in the market and the increase in workload from the upturn. The upturn in workload may also result from lower pricing structures of the products, resulting from the meeting of these objectives. Employee motivation and satisfaction will also be enhanced with their involvement in the change processes.

3.3 Exploratory research

3.3.1 Primary research data

Primary data was collected via the issued questionnaire and interviews with selected employees. It is realized that many good suggestions for capacity optimisation and potential for new technology implementation is often available from employees within the factory, however, these employees are often not given the opportunity to air their views, or feel their views are not taken seriously or implemented, therefore are not forthcoming with suggestions for improvement. With this in mind, the factory employees were given an opportunity to make these suggestions anonymously, in the form of written suggestions at the end of the questionnaire. The quantitative section of the questionnaire was drawn up to gauge the current perception of capacity and technology use and desired future levels of their utilisation.

3.3.2 Secondary research and data

Secondary data included previous cost calculations done for the building of a modular type furnace and equipment quotations received for a phased array ultrasonic testing machine.

Other current measures used at HEV were also included, such as welding touch times, welding deposition rates and costs of poor quality. These measures are recorded and reported at management level monthly, and are already considered important to the current performance of the company.

Data for the secondary objectives includes:

(a) calculating the cost resulting from inefficiencies in the production systems. This includes logistics costs, factory setup costs, opportunity costs and cost of poor quality
(b) the proposal of changes to the present mode of operation, and
(c) conducting cost-benefit analysis of the proposed changes

3.4 <u>Issues of measurement</u>

This involves a discussion of the instruments used in measuring the key variables of the study. A questionnaire was developed and was issued on a trial basis to a pilot study group of 3 people in the organisation. From feedback received, the questionnaire was modified. It was then sent to the North West University's Statistical Consultation Services for review, and a number of alterations made from the suggestions received. The questionnaire was then issued to 36 personnel within the organisation, on a hard copy basis. The range of personnel whom completed the questionnaire included members of management, workshop superintendents, workshop foremen and various levels of staff and technicians.

Due to time constraints, literacy levels of the majority of operational workers, and many personnel within the organisation not directly involved in operations, it was decided that not all employees would be issued with a questionnaire, but rather only from foreman level, through superintendents, workshop managers, operational staff and management. However, it was felt this study population would give a representative view of issues and opinions from the workshop, from those employees involved on a daily basis on the workshop floor.

3.5 Questionnaire design

The questionnaire was designed taking into account the primary and secondary objectives detailed in chapter 1, the literature review in chapter 2, internal expert opinions and the personal experience of the author.

The questions were compiled to identify factory worker's perceptions as to the current operation's effectiveness, factory layout and identified operating inefficiencies. Questions regarding the awareness, use and implementation of technology in the workplace were posed, such that improved methods of manufacture, to replace old work methods and the rearranging of old work flows, could be identified. Cost aspects of current work methods were posed, where the perception as to the implementation of technology reducing unneeded and expensive activities and improved operations were measured. Increases in efficiency, utilisation, productivity, competitive advantage, service and product quality by the implementation of technology were also measured. This formed the hypothesis of this study.

Process and capacity aspect questions were centred around current factory layouts and machine placements, including current workstation arrangements.

3.6 Sample design and sampling methods

There are currently 404 employees at HEV – this represents the target population. The full population would be all personnel working at heavy engineering companies throughout the globe.

Due to time constraints, it was decided that not all employees would be issued with a questionnaire, but rather only from foreman level, through superintendents, workshop managers, operational staff and management. This is the study population. The sample taken was therefore not random, but a convenience sample. It was felt this sample of the target population would give a representative view of issues and opinions from the workshop, from those employees involved on a daily basis on the workshop floor. The data obtained from this convenience sample was however analyzed as if it were obtained from a random sample.

3.7 Data collection methods and fieldwork practice

The proposed questionnaire was developed and issued on a trial basis to a pilot study group of 3 members of senior management for review of content validity and feedback. This feedback was received on 13 August 2011. Feedback from the University of the North West's Statistical Consultation Services regarding face validity was received on 24 August 2011 and the proposed changes and additions were made. The questionnaire was issued by the author to 36 personnel from Heavy Engineering Vereeniging. Personnel who completed the questionnaire included members of management, factory superintendents, boiler making, welding and machine shop foremen, production controllers and various levels of staff. The questionnaires remained anonymous and were completed in the personnel's own time. The last completed questionnaires were received back on 14 September 2011. Interviews with experienced superintendents and management, who had been a part of the organization for at least 10 years, were also conducted.

The following biographic categories were used in the collection of the data:

- Age, in years.
- Length of service at DCD-DORBYL, Heavy Engineering Vereeniging, in years.
- Job function at DCD-DORBYL, Heavy Engineering Vereeniging: Artisan, manager, foreman, superintendent, technician, staff or other. If other was answered, a description of the job had to be given.

The feedback rate was 66.7 % (24 completed and returned questionnaires from a total of 36 handed out), and the data was collated by the author of this dissertation.

3.8 Data capturing (gathering), editing and analysis

The data gathered, i.e. answers to the questionnaire, was collated by the author into a Microsoft Office Excel spreadsheet. The quantitative data was analysed by the Statistical Consultation Services department of the North-West University. The data analysis software package used to analyse the data was the Statistical Package for the Social Sciences Incorporated (SPSS Inc), version 18 of 2009 (SPSS, 2009). Descriptive statistical test results were provided to the author for interpretation, for the identification of possible trends and their relationship to the literature review performed in chapter 2. Test results received included a frequency analysis, basic descriptive statistics (e.g. mean, mode, standard deviation), as well as Kendall's tau for significance of non-parametric linear relationships between variables in small samples, reliability measures of the data analysed (Cronbach's alpha) and various comparisons between groups.

3.9 Shortcomings and sources of error

As the author of this mini dissertation is an employee and member of management of the organisation being analysed (HEV), and the employees completing the questionnaire were aware of this, there may be some source of error due to employees possible fear of lack of anonymity or possibly providing answers that were felt to be the wanted answers, and not the true perception of the employee. As both of these sources of error would have proven impossible to measure, they cannot be quantified. However, as the overall spirit of openness and non-victimisation for criticism has been in place within the organisation for many years, it is felt this would not have provided a large source of error in this study.

CHAPTER 4: RESULTS – PRESENTATION AND DISCUSSION

4.1 Introduction

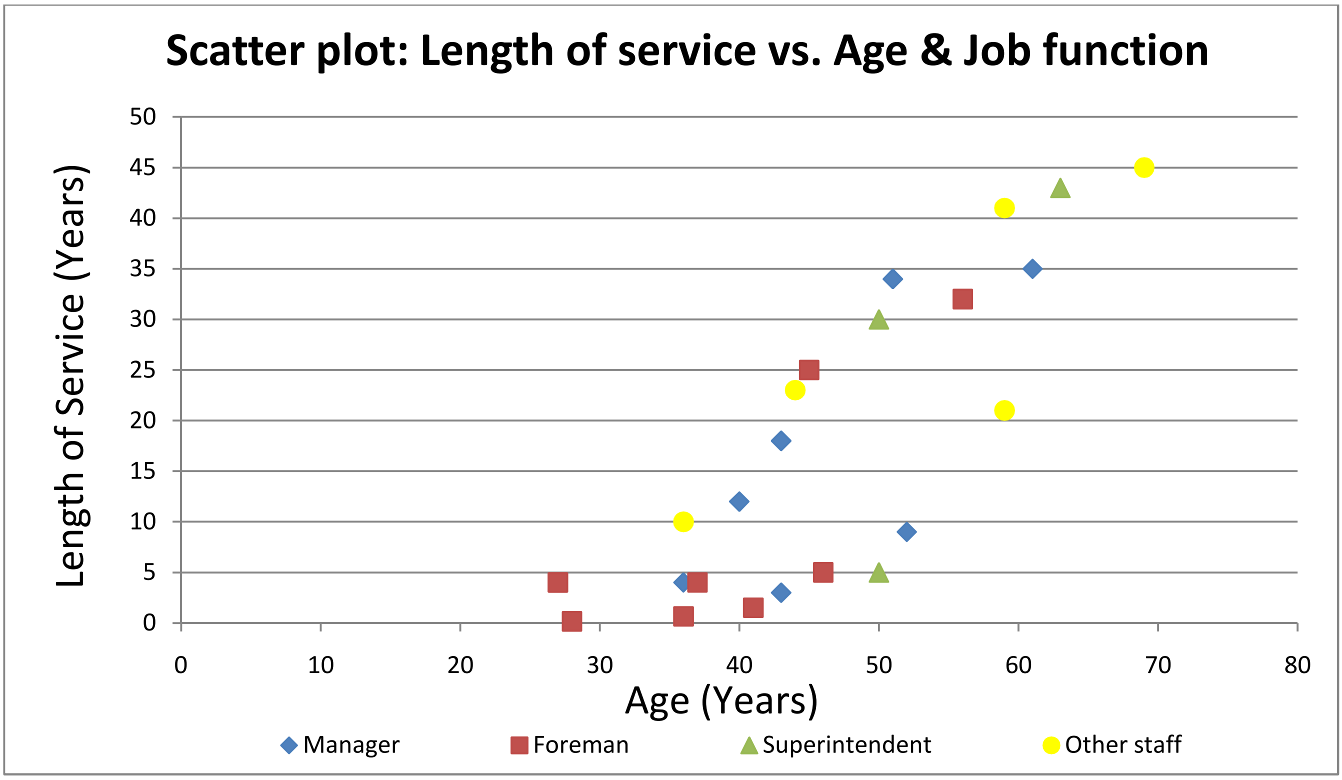
The results of the fieldwork are documented and discussed in this chapter. This includes detailing the sample profiles, presentation of results, a discussion of results by hypothesis or theme, concluding interpretations from the questionnaire and a discussion of the results of the statistical analysis, as performed by the Statistical Consultation Services of the North West University, using SPSS (SPSS, 2009).

4.2 Sample profiles

Of the 36 questionnaires handed out, 24 employees at HEV completed and returned the questionnaires, resulting in a return rate of 66.7 %. A general description of the demographics of the sample personnel is as follows:

	Years	Range (Years)	Mean (Years)	Standard Deviation (Years)
Age	27 - 69	42	45.8	11.6
Length of Service	0.17 - 45	44.8	17	15.1
Job functions of the personnel who completed the questionnaire & (number in each category)	Manager (7), Foreman (9), Superintendent (3), other staff (5)			

A scatter plot of the personnel ages, length of service and job function is presented below. It is noted there is an even distribution for length of service for the manager, superintendent and other staff job functions. For the 8 foremen who answered the questionnaire, there are 6 foremen with 5 years or less length of service at HEV, indicating a relatively newly employed core of foremen. This would suggest a possible need for additional coaching and mentoring of the newly appointed foremen, before their readiness to be appointed as possible superintendents.



Graph 1: Scatter plot of age, length of service and job function.

4.3 Presentation of results

A summary of the questions asked and results from the questionnaire are presented below. The total count for each question is 24, with means and standard deviations for each question reported.

Frequency (Total Count for each question = 24) Note: there were no missing values									
Q no	**Technology aspects: (Named F_tech)**	**Strongly agree**	**Agree**	**No opinion / neutral**	**Disagree**	**Strongly disagree**	**Mean**	**Standard Deviation**
1	I am using technology to a large extent in my job.	6	15	1	2	0	1.96	0.806
2	I would like to use the latest technology in my job.	17	6	1	0	0	1.33	0.565

3	I am using the latest technology in my job.	2	10	7	4	1	2.67	1.007
4	I have been involved in the implementation of technology in my workplace	3	15	5	1	0	2.17	0.702
5	It is important to use the latest technology in the workplace	17	7	0	0	0	1.29	0.464
6	I am aware of technology that would improve my job.	8	12	4	0	0	1.83	0.702
7	I am aware of technology that is currently not being used in my job	3	11	10	0	0	2.29	0.690
8	Our technology implementation initiatives have been successful	3	12	8	1	0	2.29	0.751
9	I have experienced resistance to change in my job, regarding the use of technology	0	16	5	3	0	2.46	0.721
10	Our customers expect us to implement the latest technology	10	10	4			1.75	0.737
11	It is important that our suppliers use the latest technology methods	11	9	3	1		1.75	0.847
12	The implementation of technology has negatively affected my work life	0	1	3	14	6	4.04	0.751
Q no	**Cost efficiency changes by implementing new technology: (Named F_cost)**	**Strongly agree**	**Agree**	**No opinion / neutral**	**Disagree**	**Strongly disagree**	**Mean**	**Standard Deviation**
13	Implementing new technology decreased unneeded activities	8	13	1	1	1	1.92	0.974
14	Implementing new technology decreased expensive activities	7	13	4	0	0	1.88	0.680
15	It is easier to identify costs after implementing new technology	4	15	4	1	0	2.08	0.717

16	It is easier to quantify costs after implementing new technology	4	17	3	0	0	1.96	0.550
17	Implementing the latest technology is expensive	7	15	0	2	0	1.88	0.797
18	Implementing technology provides cost savings in the long run	10	14	0	0	0	1.58	0.504
19	Implementing technology provides cost efficiency in the long run	11	13	0	0	0	1.54	0.509
20	New technology implemented correctly increases efficiency (efficiency = hours used vs. hours given)	12	12	0	0	0	1.50	0.511
21	New technology implemented correctly increases productivity (effectiveness of work)	11	13	0	0	0	1.54	0.509
22	New technology implemented correctly increases service and product quality	8	16	0	0	0	1.67	0.482
Q no	**Efficiency and productivity improvements though the application of new technology: (Named F_eff_prod_all)**	**Strongly agree**	**Agree**	**No opinion / neutral**	**Disagree**	**Strongly disagree**	**Mean**	**Standard Deviation**
23	Implementing new technology decreased unneeded operations or processes	6	17	1	0	0	1.79	0.509
24	Implementing technology can automate processes & functions	6	15	2	1	0	1.92	0.717
25	Implementing technology leads to job losses	1	3	8	11	1	3.33	0.917
26	Implementing technology leads to greater availability of information (to more people, more frequently)	8	15	1	0	0	1.71	0.550

27	Technology increases speed of operations	9	15	0	0	0	1.63	0.495
28	Implementing technology leads to better utilization of resources	8	16	0	0	0	1.67	0.482
29	Technology leads to an improved customer experience, i.e. through improved responsiveness to business processes	4	17	3	0	0	1.96	0.550
30	Technology related processes are vital to running a business (e.g. project reporting, email, information sharing, timeous notifications)	10	14	0	0	0	1.58	0.504
31	The implementation of technology overcomplicated some processes (where simple processes became complicated processes)	0	8	10	6	0	2.92	0.776
Q no	**Improvements in product or service quality by using new technology: (Named F_quality)**	**Strongly agree**	**Agree**	**No opinion / neutral**	**Disagree**	**Strongly disagree**	**Mean**	**Standard Deviation**
32	It is important for suppliers to improve their processes such that our input material is improved	9	13	2	0	0	1.71	0.624
33	It is important for us to improve our own internal manufacturing processes	17	7	0	0	0	1.29	0.464
34	Technology makes product and service information more readily accessible	9	15	0	0	0	1.63	0.495
35	Technology improves testing methods to detect product defects	15	8	1	0	0	1.42	0.584
36	New technology enables us to perform activities that were required but could not be performed previously by old technology methods	12	10	1	1	0	1.63	0.770

37	Correctly implementing the latest technology gives us a competitive advantage	20	3	1	0	0	1.21	0.509
Q no	**Processes & Capacity aspects:**	**Strongly agree**	**Agree**	**No opinion / neutral**	**Disagree**	**Strongly disagree**	**Mean**	**Standard Deviation**
38	The current factory layout is correctly set out to achieve good product output	0	8	6	9	1	3.13	0.947
39	There are machines that should be moved to better product output	7	9	7	1	0	2.08	0.881
40	There are processes that should be moved to better product output	8	11	5	0	0	1.88	0.741
41	There are alternate processes that we should be using to better product output	4	15	2	3	0	2.17	0.868
42	Our capacity is being optimally utilized	1	7	7	8	1	3.04	0.999
43	A process flow workstation arrangement (production line) is more suited to our product manufactured	3	7	7	5	2	2.83	1.167
44	I have been involved in a capacity improvement initiative	1	12	8	1	2	2.63	0.970
45	Our capacity improvement initiatives have been successful	0	15	7	1	1	2.50	0.780

Table 1: Summary of results from the questionnaire.

4.4 Discussion of quantitative results by hypothesis or theme

5 themes were presented in the questionnaire. These were technology aspects (questions 1 to 12), cost efficiency changes by implementing new technology (questions 13 to 22), efficiency and productivity improvements through the application of new technology (questions 23 to 31), improvements in product or service quality by using new technology

(questions 32 to 37) and process and capacity aspects regarding the current business (questions 38 to 45).

A summary of the findings for each of the 5 themes is discussed below. The reliability of these 5 themes will be discussed later, when they are used in the analysis below.

The mean results for each question were used to gauge the views of the respondents:

4.4.1 Technology aspects:

Most respondents felt they were using technology to a large extent in their jobs and wanted to use the latest technology available, feeling it was important to do so. They were aware of technology that would improve their jobs, which was currently not being used. The use of technology had generally not met with resistance to change. The respondents felt strongly that customers expected them to use the latest technology available, and they expected the same of suppliers. The implementation of technology had not negatively affected their work lives.

4.4.2 Cost efficiency changes by implementing new technology:

Most respondents strongly agreed with these questions posed. They felt that implementing new technology decreased unneeded activities and expensive activities. The identification and quantification of costs was more easily done after the implementation of new technology, and provided long run cost savings and cost efficiencies. However, the implementation of latest technology was perceived as expensive. It was found the respondents felt new technology implemented correctly increases efficiency and productivity (where efficiency is the ratio of hours used for an operation versus the hours given to perform the operation, and productivity is the effectiveness of the work performed, calculated from the product of utilization and efficiency). It was felt that new technology implemented correctly increases service and product quality.

4.4.3 Efficiency and productivity improvements through the application of new technology:

The respondents agreed that implementing new technology decreased unneeded operations or processes and automation of processes and functions could be undertaken with this implementation.

It was agreed that implementing technology leads to greater availability of information (to more people, more frequently), increases speed of operations, leads to better utilization of resources, improves the customer experience (through improved responsiveness to business processes) and is vital to the running of a business (such as project reporting, email, information sharing and timeous notifications).

The respondents were neutral as to technology implementation leading to job losses and the over complication of some processes, where simple processes became complicated processes after the implementation of technology. It must be noted that question 25 (the implementation of technology leading to job losses) may have been answered with some bias, as respondents may have answered with the loss of their jobs in mind.

4.4.4 Improvements in product or service quality by using new technology:

The respondents all mainly agreed that it is important for suppliers to improve their processes such that HEV's input material is improved, improvements to HEV's internal manufacturing processes are important and that technology allows for improvements in testing methods to detect product defects. They agreed that technology makes product and service information more readily accessible and allows for the performance of activities that are required but could not be performed previously by old technology methods. The respondents strongly agreed that implementing the latest technology gives HEV a competitive advantage.

4.4.5 Process and capacity aspects regarding the current business:

The respondents agreed there are various machines and processes that should be moved to better product output and there are alternate processes that should be used to better product output. The respondents were very divided concerning the correctness of the current factory layout for the achievement of good product output and the optimal utilization of the current capacity. They were further divided as to whether a process flow workstation arrangement (production line) was more suited to the type of product manufactured.

Most respondents had been involved in a capacity improvement initiative and felt the capacity improvement initiatives had been successful.

4.5 Discussion of qualitative results

The following suggestions for improvement were received from the written format questions. These suggestions were edited and formatted to correct grammar only, with their content remaining unchanged. The written format questions focused on process and capacity aspects regarding the current business (similar to section 4.3.5 above) and the implementation of technology (similar to section 4.3.1 above). However, these questions provided the questionnaire participants an opportunity to provide insight into aspects that could not be addressed in the rigid quantitative measurements found in the first part of the questionnaire.

4.5.1 Ergonomics question posed:

Question 1: If there was something you could change in your daily activities regarding ergonomics, work processes or work flows, what would it be? (e.g. placement of machines, additional equipment, computers, internet, capacity improvements etc.)

Suggestions:

- Implement a system for the QA department to clear their own operations when complete, and not the production department.
- Computer software updates.
- Increase our current manufacturing capacity regarding size, height and length manufacturing ability.
- Move Hausler horizontal roll into main fabrication workshop, to better utilize the additional height under the crane and crane capacity, and to allow the manufacturing lines to be under one roof.
- Install additional and latest technology tools and equipment.
- Unused machines to be moved out of the workshops.

- Utilize fixed welding stations with additional welding machines at each welding station, to minimise waiting time for the moving of welding machines.
- Improve the workshop process flow.
- Extend the heavy fabrication bay (bay 1) and increase the floor depth of this extension, such that additional crane height is created.
- Minimise breakdowns on machines, such as through regular planned maintenance.
- Continue information sharing with the workforce and allow input from the workshops as to process improvements.
- Implement a documentation control system and a logistics and software cycle computerised process.

4.5.2 Job performance question posed:

Question 2: Is there anything you would change in the way you perform your job?

Suggestions:

- Input non destructive testing (NDT) inspection operations as a lump sum operation, to save time during individual time allocation into the planned operations.
- Utilize the clocking system to its full potential.
- The implementation of a document control and flow system would improve productivity and minimise printing costs.
- Increase knowledge with regard to welding technology and latest processes available.
- The lessons learnt in the recent high performance journey training can be implemented.
- Most respondents wanted to manage at a higher level, with increased professionalism, better people management and less involvement in the finer detail – this they wanted to leave to the foremen and artisans themselves.
- The layout of the workshop was seen as important, along with the motivation of the people within the workshop.

4.5.3 Question posed:

Question 3: Is there any technology that you could suggest Heavy Engineering Vereeniging could implement?

Suggestions:

- Retrofit all machines to be computer numerically controlled (CNC), such that the latest tooling, which is only available for CNC machines, can be utilized.
- Latest welding technology, including equipment, consumables and methodologies (such as hand held submerged arc welding, tandem arc welding, welding seam tracking, welding simulator for training and alternate welding consumables).
- Technologically advanced grinding equipment.
- Phased array ultrasonic testing equipment.
- Change the flow of jobs through the fabrication shop, such that not all jobs are processed through the heavy fabrication bay (bay 1).
- Upgrade the cranes to remotely controlled cranes.
- Automated horizontal roll, to replace and improve on the current plate roll's capabilities – this will improve on the current in-process mill shell rectification after rolling.
- Implement an electronic document and process flow system.
- Implement a CAD-CAM system (computer aided design – computer aided modelling software program).
- Install a fully CNC 12.5 meter swing vertical borer.

4.5.4 Question posed:

Question 4: Has the implementation of technology negatively impacted your work life?

Responses received:

- Most respondents agreed the implementation of technology had not negatively impacted their work lives, but had rather enhanced it.
- It was felt the key to this was correct implementation of the proposed technology.
- One respondent noted that increased use of email had tended to decrease the direct communication between people.

4.6 Concluding interpretations from the questionnaire

It was evident from the responses received, most respondents were favourable to the implementation of technology in the workplace, and felt this implementation would increase productivity, efficiency and profitability and decrease costs. The key, however, was the correct implementation of technology, such that resistance to change was minimised. This would include the involvement of the workshop personnel from the outset of technology investigation and implementation initiatives.

Furthermore, the implementation of technology would enhance the customer experience through information sharing and lead to improved and more efficient use of assets, allowing for automation. Job losses were not necessarily linked to the implementation of technology, such as through automation. Key drivers for the implementation of technology included improvements in input materials and value chain processes, leading to a competitive advantage. However, there was division as to the correctness of the current factory layout, optimal process flow and full utilization of current capacity.

A number of the suggestions from the survey were followed up for costing and payback periods, and are discussed below in the conclusions and recommendations section. As these suggestions are from personnel involved in the daily factory operations, it could be concluded they would be easier to implement than if imposed as a directive from top management.

4.7 Results of the statistical analysis:

A description of the measures used, their definitions and discussion of their results is given below:

4.7.1 Statistical Significance (p-value):

The total population (N) in this study represents all personnel working at manufacturers in the global heavy engineering industry, with this sample taken from one of the manufacturers within the heavy engineering industry. Large samples tend towards normality due to the central limit theorem, in that the sampling distribution of the mean is approximately normally distributed. However, this does not imply the total population is normally distributed (Levine *et al*, 2008:268). In this study, nothing is known as to the normality of the distribution of the population or this sample. Parametric tests are used for normal distributions, whereas nonparametric tests are used for unknown distributions, as is the case in this study. For this reason non parametric methods were used during the statistical analysis of this study, when deviations from normality were severe. Non parametric methods are typically more robust methods for analysing data, in terms of violating assumptions such as normality and homogeneity, and include the use of Kendal's tau for the reporting of p values and correlation coefficients (r).

The p-value of a random sample indicates the percentage chance of the sample being representative of the population. p-values are used to determine if there is statistical significance between the responses received from the questionnaire issued to the target population (represented as the sample in this study) and the total population. The p-value gives the probability of achieving a test statistic equal to or more extreme than the sample result, given that the null hypothesis is true (i.e. there is no difference between the population and the sample means) (Levine *et al*, 2008:337). p-values less than or equal to 0.05 ($p \leq 0.05$) indicate there is a statistical difference between the distribution of the responses for the population and the sample (Ellis & Steyn, 2003:51-53).

It must be noted that larger data sets tend to return smaller p-values. Care must therefore be taken not to overly interpret samples should their p- values be below 0.05 (Ellis & Steyn, 2003:51-53).

However, as this study's sample was not random (questionnaires issued to foremen, superintendents, staff and managers from DCD-DORBYL, Heavy Engineering Vereeniging), the results cannot be generalised to be representative of the total population. Nonetheless, the p-values, indicating statistical significance, will be reported for the sake of being complete. Furthermore, as the sample taken was not random, focus will be undertaken on practical significance instead of statistical significance.

4.7.2 Practical Significance (d and r values):

In this study, practical significance is understood as a large enough difference between the means of 2 sample populations, such that these differences have an effect in practice. A difference between the means is one possible scenario for indicating statistical and practical significance. Other measures of practical and statistical significance exist, such as the linear relationship between 2 variables is measured by correlation (r).

A measure for the difference in means is the effect size, where the effect size (d) is given by the standardised difference between the means of the 2 populations, i.e. the difference between the 2 means divided by the estimate for standard deviation. For random samples drawn from populations, it is important to comment on the practical significance of a statistically significant result (Ellis & Steyn, 2003:51-53).

Effect sizes measure the magnitude of the effect, or strength of the relationship, between 2 groups of variables. Effect sizes are of real value in this study as the assumptions to use p-values are not met. Unlike statistical significance tests (where large samples tend to return small p-values), effect sizes from practical significance tests (d and r values) are independent of sample size (Becker, 2000).

Another value indicating practical significance is the r value. r is the correlation coefficient and signifies the strength of the relationship between the 2 variables. The value of r varies between -1.00 and 1.00. $r = 0$ indicates no correlation or relationship between the variables, $r = 1.0$ indicates a perfect positive relationship while $r = -1.00$ indicates a perfect negative relationship (Pallant, 2007:132).

4.7.3 Cronbach's alpha (α):

To decrease the number of elements to be individually dealt with during the discussion of responses to a questionnaire, common elements can be grouped together. However, the internal consistency of the questions or the average correlation of the items within the questionnaire must first be tested, using Cronbach's alpha (SAS, 2003). Should the groupings of questions have a Cronbach's alpha co-efficient of higher than 0.7, they can be grouped together as one theme, and provide a dimension reduction for the purposes of discussion.

5 themes or constructs were presented in the questionnaire. These were technology aspects (questions 1 to 12), cost efficiency changes by implementing new technology (questions 13 to 22), efficiency and productivity improvements through the application of new technology (questions 23 to 31), improvements in product or service quality by using new technology (questions 32 to 37) and process and capacity aspects regarding the current business (questions 38 to 45). Posing the purposeful questions within the themes provides insight into the different aspects of the 5 constructs, allowing for measurement of elements that cannot be directly measured. Cronbach's alpha can then be used to test whether the internal consistency or reliability of the grouped questions is sufficient to have initially created the constructs.

Cronbach's alpha is also used to determine how reliably the questionnaire was answered, and returns values between 0 and 1. A value of 0.8 for Cronbach's alpha is generally accepted as the appropriate minimum value for cognitive tests (such as intelligence tests), however, for ability tests a cut off of 0.7 can be used (Field, 2009:675). For this reason, 0.7 was used as the minimum cut off point for Cronbach's alpha during the analysis of data received from the questionnaire.

From the above, the questionnaire questions were grouped into sub sections, and represented various themes. The possibility of grouping the answers to these themes was verified by analysing Cronbach's alpha, where a minimum cut off of 0.7 was used.

Using this cut off, the following sets of questions were grouped together, representing the following themes:

Theme or factor name	**Description of theme or factor**	**Questions included in theme / factor**	**Mean**	**Standard Deviation**	**Cronbach's alpha for the theme / factor**
F_tech	Technology aspects – use, implementation, awareness, affects.	1 to 12	2.15	0.36	0.716
F_cost	Cost efficiency changes due to implementation of new technology (e.g. decreasing unneeded & expensive activities, cost savings)	14 to 22 (excluded Question 13)	1.74	0.33	0.725
F_eff_prod_all	Efficiency and productivity improvements through the application of new technology (e.g. automation, utilization of resources, simplification)	23 to 31	2.06	0.40	0.823
F_quality	Improvements in product or service quality by using new technology (e.g of suppliers, internal, testing methods, competitive advantage)	32 to 37	1.48	0.39	0.748

<u>Table 2:</u> Grouping of themes, using Cronbach's alpha ≥ 0.7.

The remaining questions, questions 38 to 45 (process and capacity aspects, dealing with the current factory layout, processes and capacity utilisation) returned Cronbach's alpha values below 0.7 when grouped together or in various combinations, such that their reliability when grouped could not be established. This is similar for question 13 (implementing new technology decreases unneeded activities) when grouped with its original theme of F_cost. These questions individually address the theme presented, however could not be grouped for dimension reduction purposes.

4.7.4 Kendall's Tau

Kendall's Tau is a non parametric measure used for small samples – applicable to this study as there were 24 completed questionnaires. Using Kendall's Tau to analyse the correlations or associations between variables, the above groupings of questions provided the following p-values (level of significance, 2 tailed) and correlation coefficients (r). The % variance explained between factors is expressed as r^2, i.e. the % change in one variable is explained by the change in another related variable. The correlation coefficient (r) is a measure of practical significance, in that it measures the linear relationship between the 2 variables.

Correlation between themes	p-value (significance)	Correlation coefficient (r)	r^2 (% variance explained)
F_cost and F_tech	0.024	0.355	12.6
F_cost and F_eff_prod_all	0.017	0.374	14.0
F_quality and F_tech	0.047	0.318	10.1
F_quality and F_cost	0.008	0.419	17.6
F_quality and F_eff_prod_all	0.005	0.451	20.3

Table 3: Significance and correlation coefficients between themes.

4.7.5 Correlation coefficients (r):

r is the correlation coefficient and signifies the strength of the relationship between the 2 variables or themes. The r value also indicates practical significance, where:

r = 0.1 to 0.29: small or no real practical association between the variables.

r = 0.3 to 0.49: there is a practically visible association between the variables.

r = 0.5 to 1.0 : there is a practically significant association between the variables

(Valentine & Cooper, 2003; Cohen, 1998:79-81).

From table 3 above, there is a practically visible association or correlation between the cost - technology, cost – efficiency / productivity and quality – technology themes, and a mildly practically significant association between the quality – cost and quality - efficiency / productivity themes (or constructs). All the correlations between these factors are positive, such that an increased perception of the respondents in the first factor is related to an increased perception of the respondents in the second factor.

4.7.6 ANOVA analysis:

ANOVA parametric analysis tests for differences in group means, where there are more than 2 groups involved. An ANOVA analysis was performed on the answers received from the questionnaires, to determine if the respondent's respective job functions influenced their responses to the questions posed. Statistical significance is assumed where the p-value is less than or equal to 0.05 ($p \leq 0.05$).

A parametric test may only be used on data which shows small deviations from normality (i.e. the data must have a close-to-normal distribution). The ANOVA parametric test was chosen as there were only slight deviations from normality (as determined by a Q-Q probability distribution plot) and homogeneity of variances (as determined using Levene's test). To ensure a more accurate representation, two more robust tests were also performed, those of Welsh and Brown-Forsythe. The post hoc test used was Tukey's B. It is important to note that due to the small number of respondents in each group, the analysis may be unreliable. However, the impact on the accuracy of the tests is unknown.

A discussion on the ANOVA analysis follows, with the results presented in table 4 below.

4.7.7 Results and Discussion of ANOVA analysis:

For table 4 below, only managers, foremen, superintendents and other staff returned completed questionnaires. There were no completed questionnaires received from the other 2 remaining categories, namely artisans and technicians.

Variable	Job Level	No. of Respo-ndents	Mean	Std. Dev.	p-value ANOVA	p-value Welch	p-value Brown Forsythe	No of groups identified by Tukey's B
F_tech:	Manager	7	2.25	0.28	0.36	0.06	0.31	1
	Foreman	9	2.22	0.41				
	Superintendent	3	1.83	0.14				
	Other staff	5	2.08	0.44				
F_cost:	Manager	7	1.83	0.28	0.59	0.64	0.55	1
	Foreman	9	1.70	0.43				
	Superintendent	3	1.52	0.36				
	Other staff	5	1.80	0.18				
F_eff_prod_all:	Manager	7	2.21	0.44	0.47	0.62	0.37	1
	Foreman	9	1.89	0.47				
	Superintendent	3	2.11	0.29				
	Other staff	5	2.11	0.22				
F_quality:	Manager	7	1.64	0.42	0.57	0.67	0.59	1
	Foreman	9	1.46	0.37				
	Superintendent	3	1.39	0.42				
	Other staff	5	1.33	0.39				
Question 13:	Manager	7	1.71	0.49	0.66	0.67	0.83	1
	Foreman	9	2.11	0.93				
	Superintendent	3	2.33	2.31				
	Other staff	5	1.60	0.55				
Question 38:	Manager	7	3.71	0.49	0.08	0.02	0.04	1
	Foreman	9	3.22	1.20				
	Superintendent	3	2.67	0.58				
	Other staff	5	2.40	0.55				

Table continues

					p-value			
Variable	**Job Level**	**No. of Respo-ndents**	**Mean**	**Std. Dev.**	**ANOVA**	**Welch**	**Brown Forsythe**	**No of groups identified by Tukey's B**
Question 39:	Manager	7	1.57	0.54	0.34	0.28	0.54	1
	Foreman	9	2.22	0.83				
	Superintendent	3	2.33	1.53				
	Other staff	5	2.40	0.89				
Question 40:	Manager	7	1.86	0.38	0.49	0.48	0.44	1
	Foreman	9	1.89	0.93				
	Superintendent	3	1.33	0.58				
	Other staff	5	2.20	0.84				
Question 41:	Manager	7	2.14	0.69	0.58	-	-	1
	Foreman	9	2.44	1.24				
	Superintendent	3	1.67	0.58				
	Other staff	5	2.00	0.00				
Question 42:	Manager	7	3.57	0.98	0.30	0.41	0.34	1
	Foreman	9	2.67	1.00				
	Superintendent	3	3.33	1.16				
	Other staff	5	2.80	0.84				
Question 43:	Manager	7	3.00	1.00	0.78	0.79	0.78	1
	Foreman	9	2.56	1.42				
	Superintendent	3	2.67	1.53				
	Other staff	5	3.20	0.84				
Question 44:	Manager	7	2.14	0.90	0.34	0.35	0.34	1
	Foreman	9	3.00	0.87				
	Superintendent	3	2.33	0.58				
	Other staff	5	2.80	1.30				
Question 45:	Manager	7	2.29	0.76	0.32	0.43	0.23	1
	Foreman	9	2.89	0.93				
	Superintendent	3	2.33	0.58				
	Other staff	5	2.20	0.45				

Table 4: Theme versus job function: Means, standard deviations and p-values of statistical methods used.

Except for question 38, no statistically significant differences were found when performing the above analysis (i.e. no p-values were ≤ 0.05). Question 38 proved to have a slight level of significance when using ANOVA, Welch and Brown-Forsythe analysis, returning p-values of 0.081, 0.021 and 0.037 respectively. However, when trying to establish where the differences lay, Tukey's B analysis was used as a post hoc test and this showed no statistically significant differences between the various job functions and Question 38.

From this analysis, it was concluded there were no significant differences in the mean responses of the respondents to the questions and factors posed, when grouping by the respondent's job functions.

However, as the sample was not random and the assumption of minimum group size of 10 was not met, the researcher focused on effect sizes and practical significance.

4.7.8 Effect sizes (d values) and practical significance (r values)

Effect size (ES) is a group of indices that measure the magnitude of the effect, or strength of the relationship, between 2 groups of variables. Unlike significance tests (where large samples tend to return small p-values), d values (effect size) and r values (practical significance) are independent of sample size (Becker, 2000). Sample size is 24 samples in this study.

d values are used to measure the effect size between groups of variables by measuring the standardized difference between two means. They also complement p-values. The d value is defined as:

$$d\ value = \frac{\text{absolute difference between the construct or theme means}}{\text{maximum standard deviation}}$$

Where:

d = 0.2 : there is a small or negligible effect.

d = 0.5 : there is a medium or practically visible effect.

d = 0.8 : there is a practically significant or large effect (Cohen, 1998:25).

Data sets that have a d value ≥ 0.8 are the result of a difference having a large effect, and is therefore practically significant (Ellis & Steyn, 2003:51-53). In the table below, only those d values ≥ 0.8 are highlighted in yellow.

Job functions are defined as follows: Job 2 = manager, job 3 = foreman, job 4 = superintendent, job 6 = other staff.

Factor / Theme	**Job 2 vs. Job 3**	**Job 2 vs. Job 4**	**Job 2 vs. Job 6**	**Job 3 vs. Job 4**	**Job 3 vs. Job 6**	**Job 4 vs. Job 6**
F_tech	0.07	1.51	0.37	0.96	0.31	0.56
F_cost	0.29	0.86	0.09	0.43	0.23	0.79
F_eff_prod_all	0.67	0.22	0.22	0.47	0.47	0.00
F_quality	0.42	0.60	0.73	0.18	0.33	0.13
Question 13	0.43	0.27	0.21	0.10	0.55	0.32
Question 38	0.41	1.81	2.40	0.46	0.68	0.46
Question 39	0.78	0.50	0.93	0.07	0.20	0.04
Question 40	0.03	0.91	0.41	0.60	0.34	1.04
Question 41	0.24	0.69	0.21	0.63	0.36	0.58
Question 42	0.90	0.21	0.79	0.58	0.13	0.46
Question 43	0.31	0.22	0.20	0.07	0.45	0.35
Question 44	0.95	0.21	0.50	0.77	0.15	0.36
Question 45	0.65	0.06	0.11	0.60	0.74	0.23

Table 5: Effect sizes (d values) and practical significance between job functions.

As noted above, questions 38 to 45 (process and capacity aspects, dealing with the current factory layout, processes and capacity utilisation) and question 13 (implementing new technology decreases unneeded activities) returned Cronbach's alpha values below 0.7, such that they could not be grouped together and are therefore reported separately for the various job function comparisons.

The highlighted values indicate there are practically significant differences in perception and attitude between the various job functions regarding the various aspects of technology (F_tech = questions 1 to 12), cost efficiency changes by implementing new technology (F_cost = questions 14 to 22), efficiency and productivity improvements through the application of new technology (F_eff_prod_all = questions 23 to 31), improvements in product or service quality by using new technology (F_quality = questions 32 to 37) and process and capacity aspects regarding the current business (questions 38 to 45).

The greatest number of practically significant differences were between managers and superintendents – notable for management as the superintendents report directly to management representatives. The differences occurred between these 2 groups in:

- <u>F-tech:</u> technology aspects (management mean of 2.25 vs. superintendent mean of 1.83),
- <u>F-cost:</u> cost efficiency changes by implementing new technology (management mean of 1.83 vs. superintendent mean of 1.52),
- <u>Question 38:</u> concerning the current factory layout as being correct to achieve good product output (management mean of 3.71 vs. superintendent mean of 2.67),
- <u>Question 40:</u> concerning the moving of process to better product output (management mean of 1.86 vs. superintendent mean of 1.33).

Other notable deviations that have management implications are as follows:

- <u>Question 42:</u> optimal present utilization of capacity (management mean of 3.57 vs. foreman mean of 2.67).
- <u>Question 44:</u> personal involvement in a capacity improvement initiative (management mean of 2.14 vs. foreman mean of 3.00).
- <u>Question 38:</u> concerning the current factory layout as being correct to achieve good product output (management mean of 3.71 vs. other staff mean of 2.40).
- <u>Question 39:</u> concerning the moving of machines to better product output (management mean of 1.57 vs. other staff mean of 2.40).
- <u>F-tech:</u> technology aspects: (foremen mean of 2.22 vs. superintendent mean of 1.83).
- <u>Question 40:</u> concerning the moving of process to better product output (superintendent mean of 1.33 vs. other staff mean of 2.20).

The remaining factors showed only small to medium (or practically visible) differences between the job functions and the themes presented.

The greatest implication of these differences in perception and attitude between the various job functions is the various job functions must be managed differently with regard to these themes or constructs, such as during the implementation of technology and capacity improvements (i.e. management must be sensitive to these differences).

4.8 <u>Current measures:</u>

Current measures used at HEV include welding touch times and welding deposition rates (Appendix B) and direct costs of poor quality (Appendix C). These measures are recorded and reported at management level monthly, and are considered important to the current performance of the company. They are reported in this section as they directly impact on delivery performance, capacity optimisation and customer perception of the organisation.

Current drives for improvement include:

4.8.1 Welding:

Increased usage of the tandem arc welding machines, which utilise 2 welding wires during the welding process, instead of the traditional single welding wire. These welding machines were recently reprogrammed by the equipment supplier to optimise welding parameters. Mechanical height sensing equipment, to aid in the increased automation of the welding process and to allow for tandem arc welding on the outside diameter of the mill shells, has recently been installed on some of these machines, with full roll out expected within the next few months. Other drives include reducing set up times for welding and performing grinding and welding operations simultaneously.

4.8.2 Cost of poor quality:

Investigations into the root cause of each product non conformance report (NCR) take place. NCRs are signed by departmental managers – this was implemented to aid in the resolution of NCRs and involves the departmental manager from the outset. Preventative actions are discussed and implemented and personnel training needs are identified at point of NCR occurrence. The foremen and departmental managers ensure the identified training takes place and is formally recorded on the internal training system. Training requirement and NCR root cause analysis summaries are distributed on a weekly basis to supervision and management. NCR and concession turn around time measurements, NCR trend graphs and costs are reported monthly, to executive management.

Full computerisation of the NCR system is currently in programming, to decrease the required paperwork and increase the speed of NCR resolution.

4.9 Capacity increase initiatives.

During a previous study conducted (Janse van Rensburg, 2006:57-68), 3 recommendations were made to increase capacity:

4.9.1 Moving of Vanderbijlpark machines to upgraded Vereeniging building.

This study found the upgrading of an existing factory building in Vereeniging (bays 77 and 88) and moving the machines currently located in Vanderbijlpark to this upgraded building would have cost approximately R 15 million in 2006 (Janse van Rensburg, 2006:63). Escalating by 6.2 % inflation per year (CPI SA, 2011), the cost in 2011 would be approximately R 20 million.

4.9.2 Moving of Vanderbijlpark machines to a newly built facility in Vereeniging.

This study found the construction of a new factory building in Vereeniging and moving the machines currently located in Vanderbijlpark to this new building would have cost approximately R 33 million in 2006 (Janse van Rensburg, 2006:66). Escalating by 6.2 % inflation per year (CPI SA, 2011), the cost in 2011 would be approximately R 45 million.

4.9.3 Extend the length of the heavy fabrication bay (bay 1, Vereeniging).

The study found the 27 meter wide bay could be extended by a maximum of 77 meters, due to a public road on the northern side of the bay. The factory space so provided would not be sufficient to move all the machines from Vanderbijlpark, however, this would increase fabrication capability and capacity (Janse van Rensburg, 2006:58). While the study did not provide an estimate of extending this bay, an approximate cost from 4.8.2 above can be used, due to the similarity of the build requirements. The cost in 2011 would therefore be approximately R 45 million.

All 3 of the above options exclude the relocation of the furnace from Vanderbijlpark and the purchasing of the required cranes.

It must be noted that neither of the 3 options presented above would be currently viable, given the present profitability of the business and the company requirement that any initiative has to be self funding.

However, as this study is focused on current capacity optimisation and the above 3 suggestions are capacity expansion initiatives, they will not be further explored in this study, but may form the basis of an alternate study into capacity expansion initiatives.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction and discussion of main points

The main findings obtained in this study are discussed in this chapter. The conclusions and recommendations found below are drawn from the hypothesis formulation in chapter 1, the literature study performed in chapter 2, the answers received from the questionnaire issued (chapter 3) and the investigations and discussions of the quantitative and qualitative data analysed in chapter 4.

5.2 Interpretation of results with regard to literature

The relating of the results to the literature and theory from chapter 2 are discussed below:

As described by Davis & Venkatesh (2000:14), this study confirmed their finding that the implementation of technology is more successful if there is employee acceptance of the technology. It was evident in this study that employees were more likely to accept and use a new technology if it was directly useful to their jobs and performed the required tasks well, increasing employee productivity. A demonstration of results from using the new technology was the best option and could be used as a comparison to old productivity levels, before the new technology was implemented (Davis & Venkatesh, 2000:14).

This was evident in the implementation of tandem arc welding at HEV in 2001, and again when tandem arc welding was used for the trial welding on the wind tower plates in August 2011, along with the trial horizontal welding on mill shell longitudinal flanges in June 2011. In all 3 these instances, trial welding was done within the workshops, using production welding personnel to operate the machines, under the supervision of their regular foremen. The welding superintendent was appointed as the champion of the testing and implementation process. The development of the new welding technologies and methodologies was done in full sight of the other factory personnel, whom were encouraged to view the new methods and ask questions relating to their implementation. Their involvement from the outset was deemed essential.

The interviews and questionnaire results confirmed the literature findings that natural clusters of workstations should be formed to perform production cell type operations with practical groupings for product manufacturing, such that the material flow thought the workshop can be simplified. This is in support of the Production Flow Analysis (PFA) methodology described in the literature (Hameri, 2010:233-241), used for transforming functional factory layouts to product oriented layouts.

In the literature, Hipkin (2004:245-260) proposed that South Africa has a developing economy, but displays characteristics found in developed countries. This dual world status, along with its' political history, provide a unique set of challenges, adding burden to South African managers. He proposed that some of these challenges to be addressed in the formulation of a technology policy include: affirmative action, employment equity, employee empowerment, relationships between various stakeholders, political changes and a new business climate (both local and international). This study confirmed the employee empowerment, relationships between various stakeholders and local / international climate aspects. The added burden on South African managers was further confirmed by the practically significant differences in perception and attitude between the various job functions within the organisation, regarding technology and capacity utilisation. It would therefore stand HEV well to address these issues in the formulation of their technology investigation and implementation policy.

5.3 <u>Gaps and deviations in the data, anomalies of results.</u>

It is noted the convenience sample taken from the target population is this study was relatively small, with the questionnaire issued to only 36 people in the study population, with 24 completed questionnaires returned. However, for the reasons discussed in chapter 3, it was felt this sample of the target population would give a representative view of issues and opinions from the workshop, from those employees involved on a daily basis on the workshop floor.

The greatest anomaly found in this study was the number of practically significant differences found in the perception and attitude between managers and superintendents, regarding technology aspects, cost efficiency changes by implementing new technology, the current factory layout as being correct to achieve good product output and the moving of process to better product output. This adds to the challenge of managing the business, as the workshop superintendents report directly to management representatives. Overall, management must be sensitive to the differences between the various job functions, however small, during the implementation of technology and capacity improvements.

5.4 Significance of results

From the results of the study, it was evident that most of the respondents were favourable to the implementation of technology in the workplace, and felt this implementation would increase productivity, efficiency and profitability and decrease costs. The key, however, was the correct implementation of technology, such that resistance to change was minimised. This would include the involvement of the workshop personnel from the outset of technology investigation and implementation initiatives.

Furthermore, the implementation of technology was felt to enhance the customer experience through information sharing and lead to improved and more efficient use of assets, allowing for automation. Job losses were not necessarily linked to the implementation of technology, such as through automation. Key drivers for the implementation of technology included improvements in input materials and value chain processes, leading to a competitive advantage. However, there was division as to the correctness of the current factory layout, optimal process flow and full utilization of current capacity. This would have to be taken into account during the operational management of the business.

5.5 Recommendations

The recommendations regarding the implementation of the findings and possible implementation initiatives are discussed below. These are given in their various themes.

All recommendations are evaluated on their payback time and time to achieve a Net Present Value (NPV) of R0 (Rand Zero). A NPV of R0 is used as the minimum for making the financial decision to implement the recommendation. Negative NPV's (over their project life) are financially unsound to pursue, while positive NPVs are generally financially attractive. By solving for a NPV of R0, the time to reach the financial break even point can be calculated. In alternate terms, a NPV of R0 occurs when the present value (PV) of the expenditure equals the present value of the future cost savings per year (CS) which result from the expenditure (Megginson, Smart & Graham, 2010:71).

For the interest rate used in the calculations, the current company required return on investment of 15 % for short term investments will be used in the calculations (Colegate, 2011). This required return on investment is above the current bank prime lending rate of 9 % and fixed deposit interest rate of 7 % (SARB, 2011).

For all calculations, to calculate the number of years for NPV = R0, the following applies:

- PV = present value of the expenditure to undertake the recommendation, shown as a negative as it is an outflow of cash (Rand).
- CS = present value of the future cost savings per year, by implementing the recommendation. Shown as a positive as it is an inflow of cash (Rand).
- I/year = HEV's current company required return on short term investments (15 %).
- N = number of years to reach a break even point, where NPV = R0.

5.5.1 Process and capacity aspects regarding the current business - relocation of machines and alternate equipment:

- **<u>Sachems drills</u>**

Relocation of the 2 sachems drills next to the 2 lathes, at the northern side of bay 2 in the South Works. This would save having to move the machined mill shells from bay 2 to bay 4 for drilling, once horizontal lathe machining is completed. This would result in less handling of the mills and time saved in moving the mills down bay 2 using cranes and across 2 bays on inter bay trolleys. It is estimated the average time saved by not having to move the mills in such a manner would be 5 hours per mill shell (White, 2011). At the Sachems cost recovery rate of R 877 / hour, this would equate to a total cost saving of R 4,385 per mill shell drilled in the south works of the Vereeniging plant. The capacity of the Sachems drill is 2.5 mill shells per month (Forward Load, 2011). This equates to a potential cost saving of R 131,550 per year.

Janse van Rensburg (2006:63) found the cost of rebuilding the foundations for 2 similar drilling machines to be R 680,000 in 2006. Escalating by 6.2 % inflation per year (CPI SA, 2011), the cost in 2011 would be approximately R 918,000.

Time calculation to obtain a NPV = R 0:

PV (Rand)	CS (Rand)	I/year (%)	**N (years)**
-918,000	131,550	15	**No Solution**

The no solution to the calculation shows the recommendation will not return a positive NPV. When the calculation is redone using the bank interest rate of 7 % (which could be earned by HEV if it merely earned interest on the cash in the bank instead of undertaking the expenditure in this recommendation), the time needed to achieve a NPV = R0 would be 10 years. While implementing this recommendation would save time in the manufacturing process and hereby improve operations, it would take a minimum of 10 years to be financially viable.

- **Hausler roll**

Moving of the horizontal Hausler roll from the roll shop into bay 4, such that a production line can be created. This would also avoid having to transport rolled shells on the back of a truck between 2 workshops, which are 300 meters apart. However, even though this roll is vital to the operation of HEV, it is not a bottleneck operation. Evidence of this is provided by its' usage rate of 41.7 %, based on available capacity over the last 41 weeks. The roll was used for 684 hours out of a potential maximum of 1640 hours available, on a single, no overtime shift basis (Recoveries, 2011). Therefore the time lost in moving flat plate to the roll and rolled shells back to the main fabrication workshop is not chocking the overall production system (i.e. acting as a bottleneck). While the roll's capability is essential to HEV's value chain, its optimal placement is not.

- **Modular furnace**

As the grinding mill shell sizes manufactured over the last 3 years are too large for the currently installed fixed furnaces, a number of temporary furnaces have needed to be built around the large diameter mill shells, such that stress relieve heat treatment may occur. These temporary furnaces are completely dismantled after every stress relieve heat treatment. The additional cost due to erecting a temporary furnace is R 63,714 (Kok, Reid & Snel, 2011:1), due to scaffolding, thermal blanket material, the differential cost to subcontract the furnace operation to a heat treatment operator and hired labour for the furnace assembly.

This recommendation incorporates the manufacture of a size adjustable modular type furnace, which can be moved between the 2 locations of Vereeniging and Vanderbijlpark. Pricing was obtained from 3 suppliers for the manufacture of the panels, to form the side walls and roof of the circular furnace. The lowest price obtained was R 388,000 (Nessa, 2011), with R70,200 ceramic fibre blanket to be purchased by HEV. It was determined a 100 mm diameter gas line was required to supply the correct volume and pressure of gas into the Vanderbijlpark workshop. The cost of installing the required gas line is R147,000 (Eastleigh, 2011). The Vereeniging workshop already has the correct gas feed pipes installed within the factory.

The total cost of installing the adjustable modular furnace is therefore R 689,928 (including VAT). It is estimated the cost saving per gas firing is R 27,086 (Kok, Reid & Snel, 2011:2). The number of gas firings to recover this cost is therefore 26 firings. The projected 1 year forward load for this type of required temporary furnace gas firing, draw off the D-Man management system, used for information sharing on the forward load, is 31 firings (Forward load, 2011). This shows the furnace capital cost would be recovered in approximately 10 months (Kok, Reid & Snel, 2011:3).

Time calculation to obtain a NPV = R 0:

Time in months will be used as a basis for this calculation. Straight line interest per month is therefore 15/12 = 1.25 %. Cost saving per month is 31/12 firings = 2.58 x R 27,086 saving per firing = R 69,972 saving per month.

PV (Rand)	CS (Rand)	I/month (%)	**N (months)**
-689,928	69,972	1.25	**10.59**

The NPV calculation also shows the cost of implementing this recommendation will be recovered in just over 10 months, and should be pursued as a viable investment.

5.5.2 Alternate, new technology methods - cost, efficiency and productivity improvements:

- **Horizontal SAW for longitudinal flanges**

Horizontal or hand held submerged arc welding for longitudinal flanges on split configuration mills, and general purpose factory applications. This is currently in testing, with the first round of welding trials completed. Quality improvements from weld metal deposited was proved using UT during the trial welding, and provides a solution for the high defect rates evident on longitudinal flange welding, where welding is normally performed using FCAW methodologies. The cost of creating a 2 machine weld station using this technology is R 623,866-00 (SA Welding, 2011), such that 2 such machines can weld simultaneously. Deposition rates of this process were calculated at 1.5 kg/hr, versus the traditional method of horizontal welding using FCAW, at approximately 1.0 kg/hr. This gives an improvement of 50 % for the welding deposition rate, and equates to a 33 % saving in time. With a cost rate of R 523 / hour for semi automatic FCAW, a cost saving of R 174 / hr would result by using the horizontal submerged arc process. The initial equipment cost would be paid off in 3,585 hours of work. With a recovery (forward load) of approximately 8,060 hours in the following 9 months where this technology could be directly applied, leading to an average of approximately 896 hours per month for horizontal FCAW for longitudinal mill flanges (Forward load, 2011). The initial equipment cost would then be recovered in just over 4 months.

Time calculation to obtain a NPV = R 0:

Time in months will be used as a basis for this calculation. Straight line interest per month is therefore 15/12 = 1.25 %. Cost saving per month is R174 / hour x 896 hours = R 155,904.

PV (Rand)	CS (Rand)	I/month (%)	**N (months)**
-623,866	155,904	1.25	**4.13**

The NPV calculation also shows the cost of implementing this recommendation will be recovered in just over 4 months, and should be pursued as a viable investment.

- **Punch through tandem arc SAW for wind towers**

Punch through welding trials using tandem arc machines were conducted during July, August and September 2011. These trials proved successful, with full penetration welds achieved and a welding procedure qualification obtained in October 2011. This new method of welding was investigated for new product initiatives, such as wind turbine tower manufacture. Full implementation for production work is the next phase of this project.

Success was achieved due to involving shop floor personnel from the start of the implementation of the new process, and performing trial runs within the factory, with visibility to other factory workers. Other factory workers are encouraged to ask question regarding the new process.

As this is a special purpose newly implemented welding process, with nothing of a similar nature already implemented at HEV to compare it to, a cost saving and NPV calculation could not be conducted.

- **Phased array ultrasonic testing equipment**

A new technology in ultrasonic testing (UT) equipment has recently been made available. This technology allows for all angles of testing to be scanned simultaneously using a single UT probe, such that individual probes for 0^{o}, 45^{o}, 60^{o} and 70^{o} no longer have to be used individually. A phased array UT set costs R 703,718 - including VAT (Gammatec, 2011). Trials and literature show a cost saving factor of 70 % of the time used in performing UT operations can be achieved. This equates to 70 % of R 659 / hour as a cost (recovery) rate for ultrasonic testing, i.e. R461 / hour of potential cost saving. The initial equipment cost would be paid off in 1,526 hours of work. With a recovery (forward load) of approximately 300 hours per month where this ultrasonic testing technology could be directly applied (Forward load, 2011), the initial equipment cost could be recovered in just over 5 months.

Time calculation to obtain a NPV = R 0:

Time in months will be used as a basis for this calculation. Straight line interest per month is therefore 15/12 = 1.25 %. Cost saving per month is R 461 / hour x 300 hours = R 138,300.

PV (Rand)	CS (Rand)	I/month (%)	**N (months)**
-703,718	138,300	1.25	**5.29**

The NPV calculation also shows the cost of implementing this recommendation will be recovered in just over 5 months, and should be pursued as a viable investment.

5.5.3 Improvements in product or service quality by using new technology

- **<u>Customer interfacing and communication</u>**

This may be improved by establishing a platform to facilitate information sharing with customers, such as creating an internet link for customers to access project data and progress reports. This would allow customers to gain information on their contracts (such as expected delivery and project progress) without having to request the required information and wait for a reply from HEV personnel. This would improve the overall customer experience when dealing with HEV, and would supplement the project progress reports already sent out as per contractual agreement.

- **<u>Internal communication</u>**

This may be supplemented by visual display boards in the workshops, for display and communication of target dates and commitments made by the workshops in completing operations. The following workshop in the process would then be kept informed as to progress and availability of work pieces for their operations. General company information could also be shared via this medium.

- **<u>Touch time measurements for welding</u>**

Deposition rates and touch times are currently measured for FCAW and SAW. Improvements include increased utilisation of the tandem arc SAW machines, which were fully serviced and programmed during September 2011. Software is available to automatically measure the touch times on these machines, such that manual record keeping of the hours used and the welding consumables drawn from the stores is not needed. Measurement using the consumables drawn from the stores has a timing delay added to this current method of measurement, in that consumables drawn from the stores are not always used against the measured time clocked during welding operations. This automatic touch time measurement can also be implemented on the FCAW machines. Another possibility for delivery improvement and deposition rates is the use of thicker diameter FCAW wires – this was investigated previously, but never implemented, due to a number of technical difficulties. These difficulties may have been overcome by the welding consumable suppliers, making them feasible to implement now.

- **Touch time measurements for drilling**

These touch times are currently also measured, where improvements on drilling methodologies include the implementation of high speed, high pressure drilling bits, known as YG and YES drills. Most of the drilling operations now incorporate these improved drills.

5.6 Conclusion

HEV is well positioned to capture the predicted continued growth in the mining market in which they currently operate, and to fully benefit from the energy market, which is expected to commence with product fabrication early in 2012.

Current capacities and equipment are being well utilised, but not to their optimal level. The well entrenched management information systems, measurement systems and operating procedures currently in use will aid to increase the level of utilisation of the available capacity and equipment. The implementation of technology and latest best practises within the operation will gain HEV a competitive edge, ensuring their future sustainability and market leadership. However, this implementation must be done with the input and buy in of the work force. The variances in perceptions and attitudes between the various job functions must be taken into cognisance during any capacity optimisation or technology implementation initiative. Continued capital expenditure and the current drives in research and development need to be maintained to further ensure sustainability.

Various recommendations were made based on the study. Financially viable options, calculated using payback periods and NPV's, included the purchase of phased array ultrasonic testing equipment, horizontal SAW for longitudinal flanges and a modular type furnace.

Other options, which could improve operations effectiveness, but not returning financially positive results, included the moving of the Hausler roll into the main fabrication workshop and the moving of the Sachems drills to alongside the lathes.

A number of new processes and initiatives were recommended, for which cost comparisons to current similar practices could not be performed. These included the full production implementation of the punch through tandem arc SAW for wind turbine tower manufacture, implementation of a customer interfacing and communication platform and internal communication display boards. Current practises regarding touch time measurements for welding and drilling were validated.

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APPENDICES

Appendix A – Questionnaire

Appendix B - Welding touch times and welding deposition rates

Appendix C - Direct costs of poor quality.

Appendix A - Questionnaire

Questionnaire: Optimizing Operations Effectiveness and Capacity at DCD-DORBYL, Heavy Engineering Vereeniging

This questionnaire forms part of an MBA final year research project for a mini dissertation. All completed questionnaires will remain anonymous and strictly confidential.

The purpose of this questionnaire is to gain an understanding of the current levels of technology and capacity utilisation at Heavy Engineering Vereeniging, and any future improvements in these areas you think could be made.

Thank you for your assistance in completing this questionnaire, it is greatly appreciated.

Regards, Alan Reid

Biographic information:

1) Age (years): ____________

2) Length of service at DCD-DORBYL, Heavy Engineering Vereeniging (Years): _________

3) Job function at DCD-DORBYL, Heavy Engineering Vereeniging: (Mark with an **X**)

Artisan	1	Manager	2	Foreman	3	Superintendent	4	Technician	5	Staff	6	Other	7

If other, please specify:______________________________________

For the questions below, please mark using an **X** in the box you feel best describes your opinion:

Scale: 1 = Strongly agree, 2 = Agree, 3 = No Opinion / neutral, 4 = Disagree, 5 = Strongly disagree

	Technology aspects:	Strongly agree	Agree	No opinion / neutral	Disagree	Strongly disagree
1	I am using technology to a large extent in my job.	1	2	3	4	5
2	I would like to use the latest technology in my job.	1	2	3	4	5
3	I am using the latest technology in my job.	1	2	3	4	5
4	I have been involved in the implementation of technology in my workplace	1	2	3	4	5
5	It is important to use the latest technology in the workplace	1	2	3	4	5
6	I am aware of technology that would improve my job.	1	2	3	4	5
7	I am aware of technology that is currently not being used in my job	1	2	3	4	5
8	Our technology implementation initiatives have been successful	1	2	3	4	5
9	I have experienced resistance to change in my job, regarding the use of technology	1	2	3	4	5

10	Our customers expect us to implement the latest technology	1	2	3	4	5
11	It is important that our suppliers use the latest technology methods	1	2	3	4	5
12	The implementation of technology has negatively affected my work life	1	2	3	4	5

	<u>Cost efficiency changes by implementing new technology:</u>	Strongly agree	Agree	No opinion / neutral	Disagree	Strongly disagree
13	Implementing new technology decreased unneeded activities	1	2	3	4	5
14	Implementing new technology decreased expensive activities	1	2	3	4	5
15	It is easier to identify costs after implementing new technology	1	2	3	4	5
16	It is easier to quantify costs after implementing new technology	1	2	3	4	5
17	Implementing the latest technology is expensive	1	2	3	4	5
18	Implementing technology provides cost savings in the long run	1	2	3	4	5
19	Implementing technology provides cost efficiency in the long run	1	2	3	4	5
20	New technology implemented correctly increases efficiency (efficiency = hours used vs. hours given)	1	2	3	4	5
21	New technology implemented correctly increases productivity (effectiveness of work)	1	2	3	4	5
22	New technology implemented correctly increases service and product quality	1	2	3	4	5

	<u>Efficiency and productivity improvements though the application of new technology</u>:	Strongly agree	Agree	No opinion / neutral	Disagree	Strongly disagree
23	Implementing new technology decreased unneeded operations or processes	1	2	3	4	5
24	Implementing technology can automate processes & functions	1	2	3	4	5
25	Implementing technology leads to job losses	1	2	3	4	5
26	Implementing technology leads to greater availability of information (to more people, more frequently)	1	2	3	4	5
27	Technology increases speed of operations	1	2	3	4	5
28	Implementing technology leads to better utilization of resources	1	2	3	4	5
29	Technology leads to an improved customer experience, i.e. through improved responsiveness to business processes	1	2	3	4	5
30	Technology related processes are vital to running a business (e.g. project reporting, email, information sharing, timeous notifications)	1	2	3	4	5
31	The implementation of technology overcomplicated some processes (where simple processes became complicated processes)	1	2	3	4	5

	Improvements in product or service quality by using new technology:	Strongly agree	Agree	No opinion / neutral	Disagree	Strongly disagree
32	It is important for suppliers to improve their processes such that our input material is improved	1	2	3	4	5
33	It is important for us to improve our own internal manufacturing processes	1	2	3	4	5
34	Technology makes product and service information more readily accessible	1	2	3	4	5
35	Technology improves testing methods to detect product defects	1	2	3	4	5
36	New technology enables us to perform activities that were required but could not be performed previously by old technology methods	1	2	3	4	5
37	Correctly implementing the latest technology gives us a competitive advantage	1	2	3	4	5

	Processes & Capacity aspects:	Strongly agree	Agree	No opinion / neutral	Disagree	Strongly disagree
38	The current factory layout is correctly set out to achieve good product output	1	2	3	4	5
39	There are machines that should be moved to better product output	1	2	3	4	5
40	There are processes that should be moved to better product output	1	2	3	4	5
41	There are alternate processes that we should be using to better product output	1	2	3	4	5
42	Our capacity is being optimally utilized	1	2	3	4	5
43	A process flow workstation arrangement (production line) is more suited to our product manufactured	1	2	3	4	5
44	I have been involved in a capacity improvement initiative	1	2	3	4	5
45	Our capacity improvement initiatives have been successful	1	2	3	4	5

Questions requiring written answers:

1) If there was something you could change in your daily activities regarding ergonomics, work processes or work flows, what would it be? (e.g. placement of machines, additional equipment, computers, internet, capacity improvements etc.)

2) Is there anything you would change in the way you perform your job?

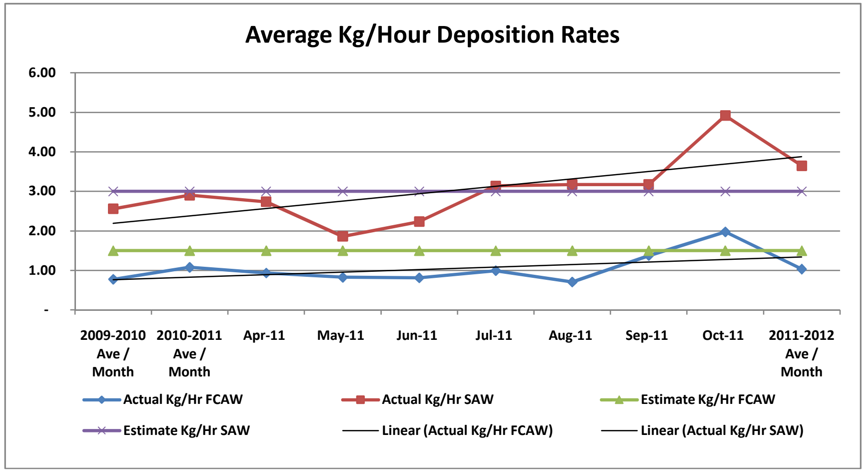
3) Is there any technology that you could suggest Heavy Engineering Vereeniging could implement?

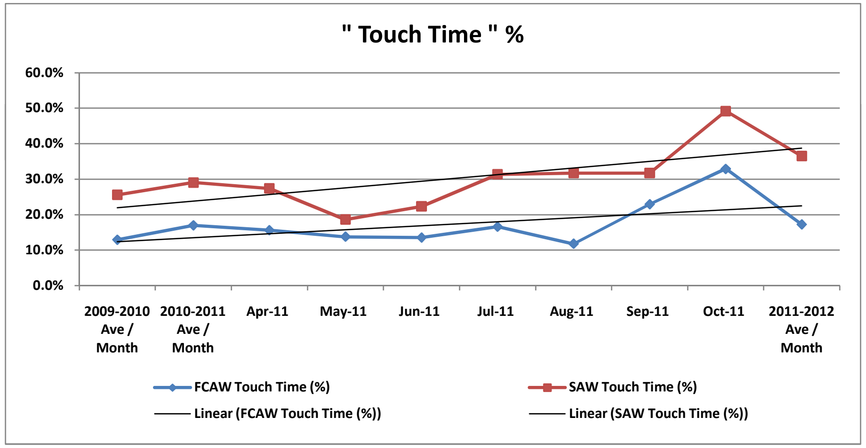
4) Has the implementation of technology negatively impacted your work life?

Thank you for your time in completing this questionnaire. Alan Reid. August 2011

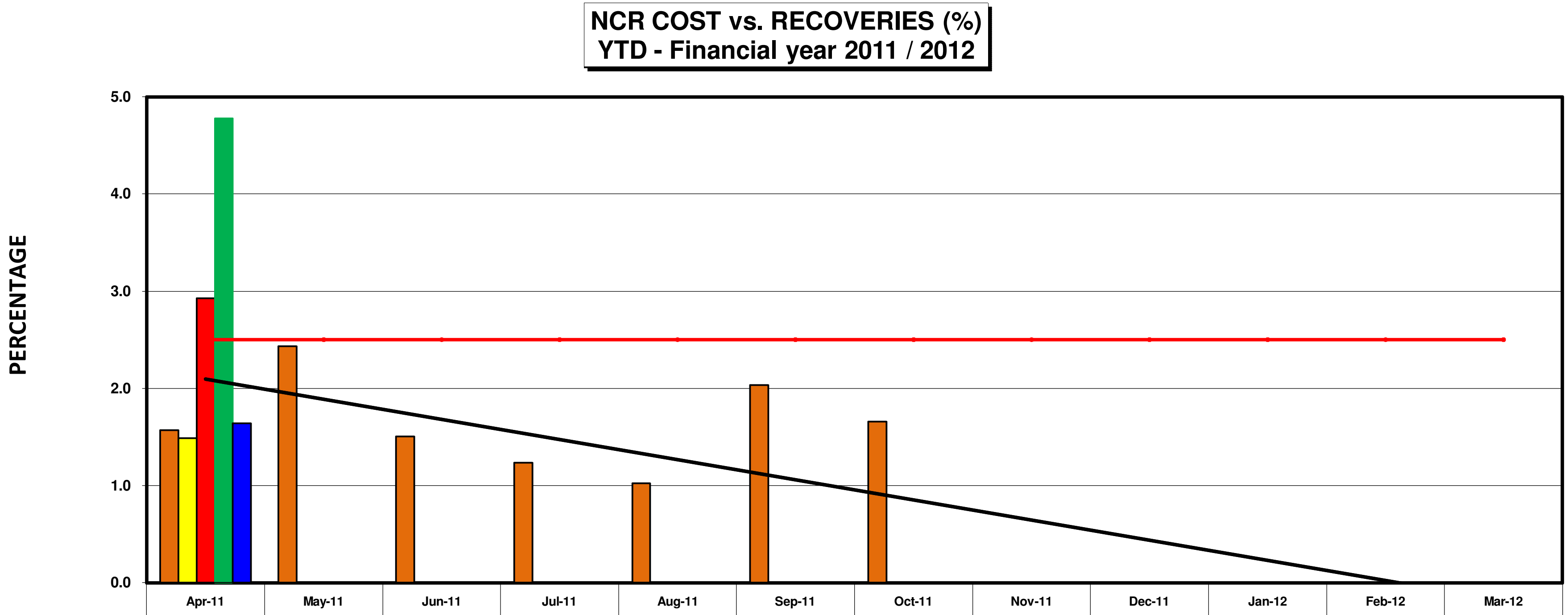
APPENDIX B - Welding touch times and welding deposition

		2009-2010 Ave / Month	2010-2011 Ave / Month	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	2011-2012 Ave / Month
Fluxcored Welding	**Cost Center**										
Hours	023	1 549	882	948	764	112	56	7	0	0	270
Hours	203	3 516	2 746	4 165	3 656	5 795	855	1 890	5 499	1 354	3 316
Hours	523						1 419	1 773	1 126	518	691
Total Hours		**5 065**	**3 628**	**5 113**	**4 420**	**5 907**	**2 330**	**3 670**	**6 625**	**1 872**	**4 277**
Fluxofil 42 E110T5 K4 1.6mm	WELE4002	0	0	0	0	0	0	0	0	0	0
Fluxofilcord 19HD or 16 (1.6mm)	WELE4007	4 166	3 240	2 592	2 400	3 184	1 520	1 552	8 444	3 056	3 250
Metal Cored & FCAW Primacore wire	WELE4008/9		1 143	1 085	825	0	25	125	0	0	294
Fluxofil 20 E81ti-ni1 1.6mm	WELE4010	461	221	1 952	1 072	2 464	1 184	1 376	2 288	1 296	1 662
Total Kg drawn from Stores		**4 627**	**4 604**	**5 629**	**4 297**	**5 648**	**2 729**	**3 053**	**10 732**	**4 352**	**5 206**
Efficiency Adjustment		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
Adjusted Kg deposited		3 933	3 913	4 785	3 652	4 801	2 320	2 595	9 122	3 699	4 425
Estimate Kg/Hr FCAW		1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Actual Kg/Hr FCAW		**0.78**	**1.08**	**0.94**	**0.83**	**0.81**	**1.00**	**0.71**	**1.38**	**1.98**	**1.03**
Deposition Rate (@100% arc time)		6	6	6	6	6	6	6	6	6	6
Deposition Hours		655	617	797	609	800	387	433	1520	617	737
FCAW Touch Time (%)		**12.9%**	**17.0%**	**15.6%**	**13.8%**	**13.5%**	**16.6%**	**11.8%**	**22.9%**	**32.9%**	**17.2%**
Number of Months				1	2	3	4	5	6	7	
Sub-Arc Welding	**Cost Center**										
Hours	024	49	219	268	0	0	0	0	0	0	38
Hours	204	1 935	1 441	2 724	1 092	732	1 299	1 727	969	1 618	1 452
Hours	524						243	3	0	100	49
Total Hours		**1 983**	**1 661**	**2 992**	**1 092**	**732**	**1 542**	**1 730**	**969**	**1 718**	**1 539**
Transarc 70-2 4mm	WELE1134	5 100	2 070	0	0	0	0	0	0	0	0
Lincoln L61 4 mm	WELE6009	0	2 622	7 435	1 650	1 469	4 587	5 603	2 638	8 622	5 334
Oerlikon SD31N 4 mm	WELE9002	82	231	925	425	200	350	0	500	0	400
Total Kg drawn from Stores		**5 181**	**4 923**	**8 360**	**2 075**	**1 669**	**4 937**	**5 603**	**3 138**	**8 622**	**5 734**
Efficiency Adjustment		98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
Adjusted Kg deposited		5 078	4 825	8 193	2 034	1 635	4 839	5 491	3 076	8 450	5 620
Estimate Kg/Hr SAW		3	3	3	3	3	3	3	3	3	3
Actual Kg/Hr SAW		**2.56**	**2.91**	**2.74**	**1.86**	**2.23**	**3.14**	**3.17**	**3.17**	**4.92**	**3.65**
Deposition Rate (@ 100 % arc time)		10	10	10	10	10	10	10	10	10	10
Deposition Hours		508	482	819	203	164	484	549	308	845	562
SAW Touch Time (%)		**25.6%**	**29.1%**	**27.4%**	**18.6%**	**22.3%**	**31.4%**	**31.7%**	**31.7%**	**49.2%**	**36.5%**





APPENDIX C - Direct costs of poor quality



	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12
PERCENT (%)	1.6	2.4	1.5	1.2	1.0	2.0	1.7	0.0	0.0	0.0	0.0	0.0
Previous Year = 2008 / 9	1.5											
Previous Year = 2009 / 10	2.9											
Previous Year = 2010 / 11	4.8											
Year to date Ave	1.6											
NCR COSTS (R)	225 070	241 021	182 274	138 979	111 574	290 660	200 224					
RECOV. VALUE (R)	14 322 000	9 902 000	12 100 000	11 280 000	10 884 382	14 276 000	12 070 000					
TARGET	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

MONTH	2008/9 AVE	2009/10 AVE	2010/11 AVE	YTD total	YTD AVE	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12
NCR COSTS (R)	205 184	339 033	439 474	1 389 802	198 543	225 070	241 021	182 274	138 979	111 574	290 660	200 224					
RECOV. VALUE (R)	13 779 428	11 587 917	9 191 083	84 834 382	12 119 197	14 322 000	9 902 000	12 100 000	11 280 000	10 884 382	14 276 000	12 070 000					
PERCENT (%)	1.5	2.9	4.8	1.6	1.6	1.6	2.4	1.5	1.2	1.0	2.0	1.7					
TARGET	1.5	1.5	1.5	1.5	1.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5