RESOURCE EFFICIENT PROCESS CHAIN STRATEGIES FOR GLOBAL COMPETITIVE MANUFACTURERS

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ABSTRACT

In order for third world country suppliers to stay competitive in the global market, innovative and resource efficient process chains need to be a part of their manufacturing strategy. In this study the effect of combining the Overall Equipment Effectiveness (OEE) software and custom machinery on performance, costs, and losses have been evaluated. This study determines the effects of using customised purpose built machinery over conventional machinery for mass production of specific parts. OEE software was used to monitor the production rate of the parts and to give crucial feedback to the machine operators and management. The cycle times, costs, overall benefits, and drawbacks were compared using the different machinery. The customised purpose built machinery produced a higher Overall Equipment Effectiveness compared to conventional machinery. OEE can play a vital role in a supplier's long-term manufacturing strategy.

Keywords: Overall Equipment Effectiveness (OEE), Purpose Built Machinery, Resource Efficiency, Process Chains

INTRODUCTION

During the last decade there has been a world manufacturing trend to move beyond optimisation achieved exclusively through improved cutting parameters. Research focus has shifted to enhancing the resource efficiency of the entire process chain (Thiede, Bogdanski, & Herrmann, 2012). Dramatic changes in the manufacturing environment over the past decades can be seen in the change from a seller's market to a buyer's market, increasing globalisation, and the environmental awareness of both the customers and the suppliers (Dombrowski, Intra, Zahn, & Krenkel, 2016). This could be a problem for suppliers all over the world who are not able to adapt to the market change. Research (Bellgran & Säfsten, 2010), (Samson, 1991), (Skinner, 1986) suggests that it is no longer adequate enough to adapt and control manufacturing by short-term targets in equipment effectiveness but rather through long-term strategies.

Overall Equipment Effectiveness (OEE) can be used as a tool to determine when the company has outgrown its capacity and when substantial long-term investment in new custom purpose built machinery is needed. Overall Equipment Effectiveness is a vital element of improvement strategies such as Lean and Total Productive Maintenance (TPM) (Koch, 2007). OEE can be traced back to Japan where Seiichi Nakajima first described the OEE method as a central component of TPM (Nakajima, 1982). OEE is used to discover the 'hidden machine' and improvements can then be made to the manufacturing methods/systems to unlock the potential work that is normally lost due to not effectively using the machine (Hansen, 2005). A large amount of capital is often invested to design, build, and implement a system to produce a certain product uniformly and at a higher rate while being more resource efficient. However, sometimes an investment does not pay off due to the machine not being fully utilised and having a low OEE. This can be avoided by monitoring the OEE of existing machines in the plant and determining if there is room for improvement. The customer and the amount of orders should also warrant whether a new machine is needed or not. The method for calculating the machines OEE can be observed in Figure 1 below.

$$Availability\ rate = \frac{Actual\ Production\ Time}{Potential\ Production\ Time} = \ ...\%$$

X

$$Performance\ rate = \frac{Actual\ Output}{Theoretical\ Output} = \ ...\%$$

X

$$Availability\ rate = \frac{Actual\ Production\ Time}{Potential\ Production\ Time} = \ ...\%$$

=

OEE % =

Availability Rate

X

Performance Rate

X

Quality Rate

Figure 1 OEE Calculations adapted from (Koch, 2007)

One of the challenges faced by third world country suppliers is economic instability. This leads to rising costs due to high inflation rates. As a third world country, South Africa has a higher inflation rate than first world countries. As of January 2016, South Africa's inflation rate was 6.20%, which is substantially higher than first world countries like USA (1.40%), Germany (0.50%), and the UK (0.30%) (Trading Economics, 2016).

In order for third world country suppliers to stay competitive in the global market, new resource efficient innovations need to play a role in their manufacturing process chains and long-term strategic decisions. In order to obtain a manufacturing contract from an international buyer the price of the products need to stay competitive and because it's a buyer's market some customers demand a 0% increase in price over several years (Winkler & Slamanig, 2011). This brings some challenges to suppliers as they experience rising costs annually such as labour and overheads due to inflation. The supplier also needs to increase their profits in accordance with inflation throughout the years in order to have cash flow for future projects and investments. Therefore, the only element that the supplier has control over is the rate at which the company can produce quality products at a more resource efficient rate. Custom purpose built machinery is machinery that has been built or altered in order to manufacture a specific part in the most resource efficient way. Resource efficiency can be in the form of, but is not limited to, time, material, costs, energy, or labour. Most custom built machinery is built around the process chain of a certain component and each aspect of the chain is broken down, refined, and made more efficient.

The objective of this research is to determine the difference in resource efficiency of conventional machinery versus custom purpose built machinery with regards to cycle time and costs using OEE software. This study took place at a manufacturing small to medium-sized enterprise (SME) called Hansen's Engineering. Hansen's Engineering was established in 1956 and is a 3rd generation family business, situated in Port Elizabeth, South Africa. The company has been producing parts solely for the automotive industry since 2001.

RESEARCH METHODOLOGY

In order to record sufficient manufacturing data, two machines had to be analysed and tracked over a 4 month period. One conventional machine and one custom purpose built machine were compared. The machines were to produce the same component over the 4 month period and all of the data throughout the 4 months would be recorded by the plants OEE software. The process can be observed in Figure 2 below.

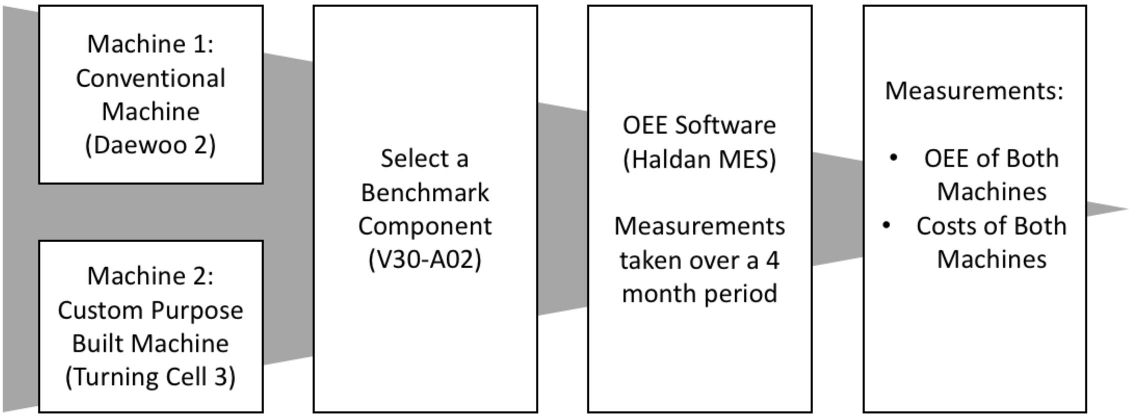

Figure 2 Research Process Diagram

The conventional machine is a Doosan Lynx 220L Compact Turning Centre (Made in Taiwan) and it is equipped with a bar feeder. This machine has been allocated the name Daewoo 2 and can be observed in Figure 3 below. This machine requires a skilled operator to run and the machine runs 7.5 hours per shift for 3 shifts a day. The production information for Daewoo 2 is displayed in Table 1.

Table 1 Daewoo 2 production information

Daewoo 2 Information	**Values**
The initial cost of Daewoo 2	R600 000
Number of workers required for Daewoo 2 to run effectively	1
Labour costs of Daewoo 2	R45/hr
Average Theoretical cycle time of Daewoo 2 for V30-A02	150/hr
The maximum output of the Daewoo 2 at 100%	150 x 7.5hr

The shifts are not 8 hours long on this machine as 30 minutes of production is lost when the operator goes on a tea break.

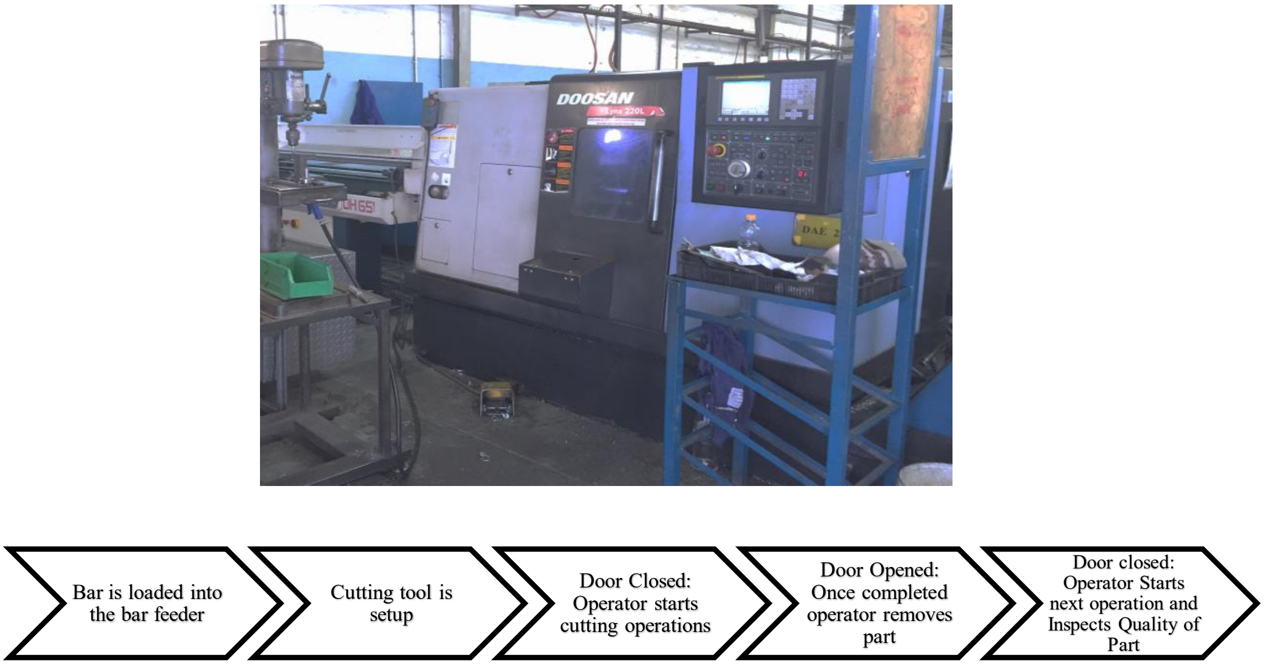

Figure 3 The conventional machine (Daewoo 2) and its process chain

One could note from the Daewoo 2 process chain that a lot of time is lost due to the door being opened and closed. If the door was kept open and a human operator was running the machine it would violate South African Health and Safety Regulations.

The customised purpose built machinery consists of several components. The cell consists of a Quick-Tech DAC-42 CNC Lathe (Made in Taiwan), a bar feeder, a Motoman HP6 robotic arm, a quality inspection unit, and a swarf compactor. The quality inspection unit and swarf compactor were manufactured specifically for Hansen's Engineering by Granroth Engineering. This manufacturing cell has been allocated the name Turning Cell 3. Turning Cell 3 was customised in order to be more resource efficient when producing components like V30-A02 (In Figure 5 below). Turning Cell 3 requires only 1 unskilled worker to monitor 5 cells. The 5 cells run for 8 hours per shift for 3 shifts a day. The production information for Turning Cell 3 can be observed in Table 2 below.

Table 2 The customised purpose built machinery (Turning Cell 3) production information

Turning Cell 3 Information	**Values**
The initial cost of Turning Cell 3	R1 050 000
Number of workers required for Turning Cell 3 to run effectively	1/5
Labour costs of Turning Cell 3	R26/hr
Average Theoretical cycle time of Turning Cell 3 for V30-A02	220/hr
The maximum output of the Turning Cell 3 at 100%	220 x 8hr

The process chain of Turning Cell 3 as well as a picture of the setup can be observed in Figure 4 below.

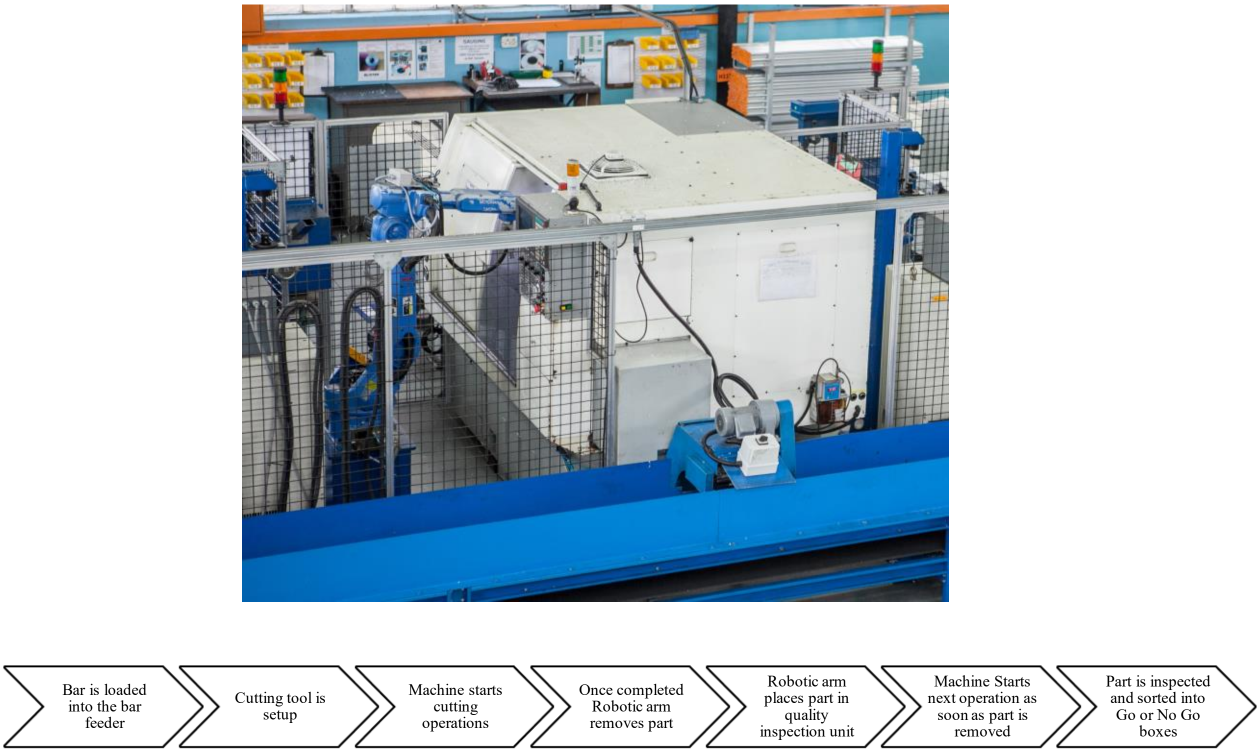

Figure 4 The customised purpose built machinery (Turning Cell 3) and its process chain

The process chain of Turning Cell 3 is completely automated from bar to box. Turning Cell 3 uses minimum quantity lubrication (MQL) when cutting as dry swarf is more valuable than wet lubricated swarf. The swarf is then continuously conveyed to a swarf compactor which compacts the swarf into single billets making them more valuable and easier to sell to scrap dealers. Unlike Daewoo 2, Turning Cell 3 makes use of a robotic arm to remove the components from the working area. This means the door can stay open throughout the machining process which substantially decreases the cycle time.

In order to compare the capabilities of the customised purpose built machinery versus the conventional machines a component that is currently being manufactured on both machines had to be selected. The benchmark component is the V30-A02 which is an aluminium product used in the automotive industry in anti-vibration dampeners on vehicle suspension arms. Samples of V30-A02 are displayed in Figure 5 below.

Figure 5 The Selected V30-A02 Aluminium Benchmark Component

Haldan MES software was utilised to collect a large amount of significant data and to accurately compare the conventional machine to the custom purpose built machinery. Haldan MES is an OEE software which measures the machines availability, performance, and quality in order to visually display all of the loses and potential of the machine (Haldan Consulting, 2014). Haldan MES reads signals off the machines Programmable Logic Controller (PLC) in order to collect the relevant data which is stored in a Structured Query Language (SQL) database on a central server in the factory. The software then converts the relevant data into valuable information that can be displayed throughout the factory and the workers can then identify what is limiting the higher effectiveness (Hansen, 2005). This information can also be utilised to make strategic company decisions and also motivate substantial investments. The OEE data of the Daewoo 2 and Turning Cell 3 were recorded for 4 months from the 1st of July 2015 until the 31st of October 2015. The theoretical product output was compared to the actual output for each of the machines using the OEE software.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The OEE percentages for each machine and all of the shifts are displayed in Table 3 below.

Table 3 OEE for the 4 months (1st of July 2015 until the 31st of October 2015)

Machine	July 2015	August 2015	September 2015	October 2015	Total
Daewoo 2	82.1	81.4	81.6	82.5	81.9
Turning Cell 3	83.1	84.8	85.5	86.7	85

It can be noted from Table 3 that the OEE's for Daewoo 2 and Turning Cell 3 are very near to each other. Daewoo 2 has an average OEE of only 3.1 % less than Turning Cell 3. This indicates that both Daewoo 2 and Turning Cell 3 are being adequately utilised and are making use of the 'hidden machine'. Turning Cell 3, however, has a higher output of product due to the faster cycle times and resource efficient process chain. It can also be observed that the OEE for Turning Cell 3 is consistently higher than the OEE of Daewoo 2, however, the standard deviation of Daewoo 2 is less than the standard deviation of Turning Cell 3 which means the production output of Daewoo 2 is more consistent. A breakdown of the total OEE for the 4 months for each machine can be observed in Figures 6 and 7 below.

Figure 6 The conventional machine (Daewoo 2) OEE charts

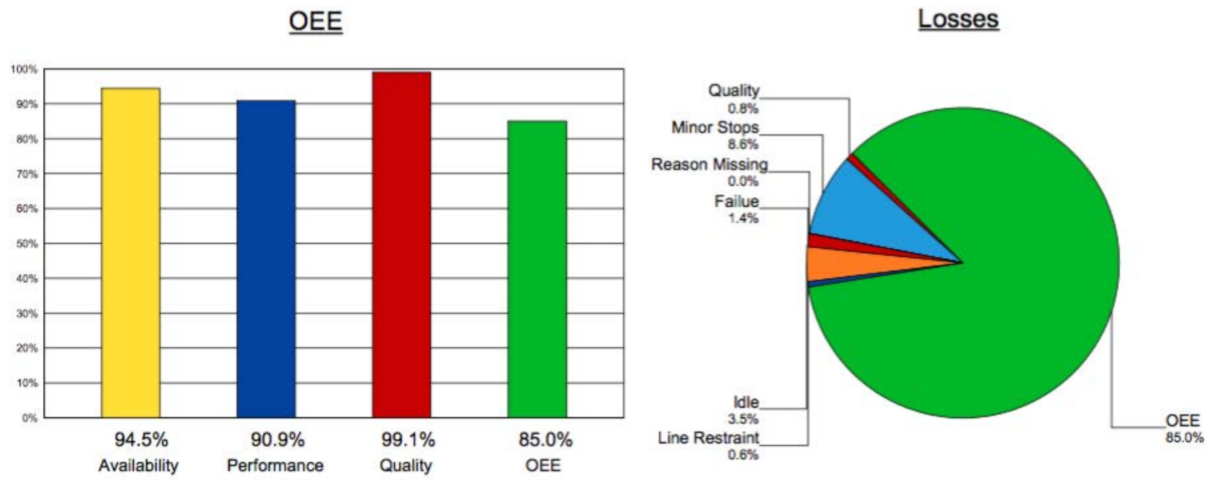

Figure 7 The customised purpose built machinery (Turning Cell 3) OEE charts

One could observe from the pie chart in Figure 6 that the Idle is 10.0%. This is mostly due to the 30 minute tea break taken by the operator. While 30 minutes of production is lost due to a tea break with Daewoo 2, with Turning Cell 3 the parts are still produced while the workers are on the tea break. In comparing Figures 6 and 7 one could observe that the custom built machinery has a higher availability than the conventional machinery. Labour costs for the custom purpose built machinery is considerably less than the conventional machinery due to the fact that the worker at the Turning Cell 3 only has to change the part boxes when they are full and this requires a lot less skill than the that needed by the operator of Daewoo 2. The labour costs per shift for the different machines are compared in Table 4 below.

Table 4 Labour costs for the conventional and custom purpose built machines

	Labour Cost	Labour Costs per Shift (per machine)
The conventional machine (Daewoo 2)	R45/hr	R360
The customised purpose built machinery (Turning Cell 3)	R26/hr	R41.6

The labour costs of the custom purpose built machinery is 88.4% less than the labour costs of the conventional machinery. This shows the custom purpose built machinery is more resource efficient in terms of labour than the conventional machinery. The initial investment on the custom purpose built machinery is also warranted as the cycle time is quicker and the labour is cheaper. The theoretical product output, scrap, and actual output of the Daewoo 2 and Turning Cell 3 can be observed in Table 5 below:

Table 5 OEE performance data for both machines

Machine	Theoretical Output	Minor Stop	Speed Loss	Scrap	Actual Good	Actual Yield
Daewoo 2	166723	-10964	0	-72	155926	94%
Turning Cell 3	495925	-45270	0	-4185	446276	90%

The scrap amount from Turning Cell 3 is considerably high. This could be due to the fact that the quality inspection unit is more accurate than the operator at the Daewoo 2 and therefore rejects a lot more parts than the Daewoo 2 operator. This has its positives, as the quality is always consistent and up to the standards of the customer. At the same time due to the Minimum Quantity Lubrication (MQL) of Turning Cell 3 the swarf is dry and is therefore more valuable as scrap. The actual output of Turning Cell 3 is 2.86 times greater than the actual output of Daewoo 2. This is a considerable difference and would definitely justify investing in the custom purpose built machinery. A comparison in cost and cycle times of the different machines is displayed in Table 6 below. A German company was prompted to quote Hansens Engineering on a custom purpose built machining centre, which could manufacture products like V30-A02 in the shortest possible time. The cost and theoretical cycle time of the benchmark German machine are also displayed in Table 6.

Table 6 Initial cost and theoretical cycle times of the machines

	Cost of Machine	Theoretical Cycle Time
The conventional machine (Daewoo 2)	R600,000	24 s
The customised purpose built machinery (Turning Cell 3)	R1,050,000	16.36 s
German Machine (Benchmark)	R6,000,000	3 s

If one compares the machines used in this study to machines in a first world country (Germany), you would find that the machines built in the first world country are more expensive and have substantially faster cycle times. To put it into perspective, a machine that does the same component (V30-A02) from a German company would cost almost 6 times more than the one modified in South Africa. However, the cycle time for the very same product would also be 5 times faster. The problem with the benchmark machine from Germany is that the cycle time is too fast and if it ran at an 80% OEE it would produce more parts than what is required by the customer and this would create large inventories. Changeover is also less flexible with the German Machine.

In comparing the OEE data from the two machines it was apparent that the investment of purchasing Turning Cell 3 was warranted. This investment could have been justified before any investment was made through the OEE data. Once a manufacturing cell has a significant OEE value for a number of months this indicates what the actual production rate of the cell is and whether a new machine is needed in order to keep up with the customers' demands.

CONCLUSION

In this study the effects of using customised purpose built machinery over conventional machinery for mass production of specific parts were evaluated using Overall Equipment Effectiveness (OEE) software. The software was used to monitor the production rate and to provide crucial feedback to the machine operators and management. The customised purpose built machinery produced a higher Overall Equipment Effectiveness compared to conventional machinery. This results in less change overs and inventory as the machines can produce the component at the same rate as that the customer requires making it more flexible to change the product mix. The investment costs of the improved resource efficient process chain was also justified through the OEE data. Future works include the commissioning of an automated purpose built machine that will be able to machine, wash, inspect, and pack the parts without any operators.

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