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Investigating the Effects of Automating Process Chains towards Sustainable Manufacturing in South Africa

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Abstract

Automation of processes is becoming increasingly popular within manufacturing. However, in third world countries such as South Africa, automation could lead to the loss of jobs and even higher unemployment. In order to remain globally and locally competitive, companies need to invest in new technologies of which automation is a highly influential aspect. Thus a study is deployed to determine when a company should automate a process and when a semi-automated process is sufficient in the process chain. To ensure a close to optimum operation, a balance between workforce skill development and profit needs to be determined. In this study, the effects of automating process chains were evaluated. A semi-automated process chain that included a manual labor aspect was used to manufacture small aluminium automotive components and was compared to an automated process with regards to machine effectiveness and labor resources. The automated process derived a higher profit margin due to the high availability of the machine and the lower labour costs. Suggestions were given to increase the profit margin without the loss of labour.

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1. Introduction

Automation is defined as the execution of a function by a machine agent (such as a computer) that was previously carried out by a human [1]. The automation evolution was brought on by the development of the digital computer and now plays a role in our everyday lives [1]. The importance of automation of machinery and processes in the manufacturing sector has increased dramatically in the recent years [2]. Technologies such as automation can be classed as a disruptive force which, if not managed properly, could lead to loss of jobs and therefore contribute to the high unemployment rate. However, if managed properly, automation could lead to the creation of new jobs as new high skilled positions are created and a competitive edge is achieved through the correct implementation of automation. South Africa has a worryingly high unemployment rate of 25% in 2014 according to Stats SA [3]. The breakdown of the skill distribution is as follows: 25% are skilled, 46% are semi-skilled, and 29% are low skilled [3].

When a company chooses to fully automate a process to stay competitive, an opportunity is missed to develop people and skills in the community around the business. In a struggling third world economy such as the one South Africa has, a balance between profit and people development must be found. But how can a company in a third world country stay competitive when costs are always rising due to the high inflation rates?

One of the challenges faced by third world country suppliers is economic instability. 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%) [4].

For third world country suppliers to stay or become globally competitive the following two elements need to be part of the company's growth strategy: resource efficient innovations and effective use of manufacturing equipment. Table 1 shows the competitiveness imperative model that was developed by Erik Hagedorn-Hansen to determine the rates at which productivity needs to increase in the company as well as the rates at which the production costs needs to decrease in order for the company to maintain its competitive edge.

Table 1: Competitiveness Imperative Model [5]

		Year					
	Annual Increase	**0**	**1**	**2**	**3**	**4**	**5**
Material	0%	R 50.00	R 50.00	R 50.00	R 50.00	R 50.00	R 50.00
Labour	9%	R 15.00	R 16.35	R 17.82	R 19.43	R 21.17	R 23.08
Overheads	6.5%	R 25.00	R 26.63	R 28.36	R 30.20	R 32.16	R 34.25
Units/Hr		**100**	**109**	**119**	**131**	**144**	**158**
Production Cost		**R 40.00**	**R 39.35**	**R 38.66**	**R 37.92**	**R 37.14**	**R 36.30**
Profit	6.5%	R 10.00	R 10.65	R 11.34	R 12.08	R 12.86	R 13.70
Price to Customer	0%	**R 100.00**	**R 100.00**	**R 100.00**	**R 100.00**	**R 100.00**	**R 100.00**
Production Cost		**0%**	**-2%**	**-3%**	**-5%**	**-7%**	**-9%**
Productivity		**0%**	**9%**	**19%**	**31%**	**44%**	**58%**

When contracting with Original Equipment Manufacturers (OEM) and tier suppliers, companies in first world countries often require the price of the manufactured product to remain constant throughout the term of the contract.

This is due to the fact that an annual increase of ±6% for inflation is not common practice in first world countries as it is in countries such as South Africa. So to tender for an offshore contract and to be successful in delivering the product at a constant price to the customer, manufacturing suppliers need to decrease production costs and increase productivity throughout the contract term to stay competitive. This study provides a model which utilises Overall Equipment Effectiveness (OEE) to determine in which area (automation, semi-automation) a mass production manufacturing company should focus in order to increase productivity and decrease production costs.

OEE can be used as a visual tool, to give crucial feedback to factory workers and management in a company. Overall Equipment Effectiveness is a vital element of improvement strategies such as Lean Tools and Total Productive Maintenance (TPM) [6]. OEE can be traced back to Japan where Seiichi Nakajima first described the OEE method as a central component of TPM [7]. OEE is used to discover the 'hidden machine' the production performance of the machine in question. 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 [8]. New strategies and systems/methods can be tested using OEE data. Machine operators can iteratively change the way they perform tasks and can see the effects of these changes on the machines OEE dashboard. The method for calculating the machines OEE can be observed in Figure 1 below.

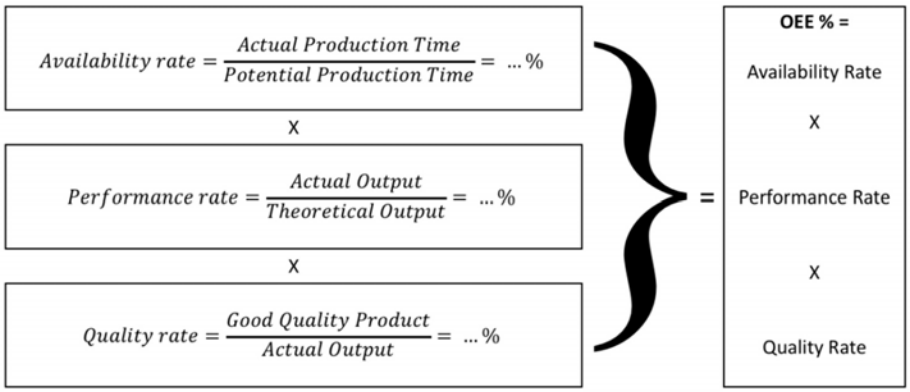

Figure 1 OEE Calculations adapted from [2]

2. Experimental Setup and Design

In order to compare an automated process chain to a semi-automated process, two manufacturing cells were monitored over a four-month period, one being an automated cell and the other a semi-automated cell. Both cells produced the same component so the product process chain did not vary throughout the observation period. The component is the V30-A02 which is an aluminium product used in the automotive industry in anti-vibration dampeners on vehicle suspension arms. The two different cells were designated the names Daewoo 2 and Turning Cell 3 by the company, Hansen's Engineering, and will be used in this study accordingly. Daewoo 2 is the semi-automated cell and Turning Cell 3 is the automated cell.

Daewoo 2 is a Doosan Lynx 220L Compact Turning Centre and it is equipped with a bar feeder. Daewoo 2 can be observed in Figure 2 below. This cell requires a semi-skilled operator to run. The cell runs 7.5 hours per shift for 3 shifts a day. The production information for Daewoo 2 is displayed in Table 1. 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 as prescribed in the labour law agreement. 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 who would be running the machine will violate South African Health and Safety Regulations.

Table 2: Semi-automated cell (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

Figure 2 The semi-automated cell (Daewoo 2) and its process chain

Turning Cell 3 consists of several machines. The cell consists of a Quick-Tech DAC-42 CNC Lathe, 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. Turning Cell 3 originally started with the same equipment as Daewoo 2 but was customised to be more resource efficient when producing components like the V30-A02. Turning Cell 3 requires only one unskilled worker to monitor five cells. The five cells run for eight hours per shift for three shifts a day. The production information for Turning Cell 3 can be observed in Table 3 below. The process chain of Turning Cell 3 as well as a picture of the setup can be observed in Figure 3 below. The process chain of Turning Cell 3 is completely automated from bar to box. 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.

Table 3: Automated cell (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

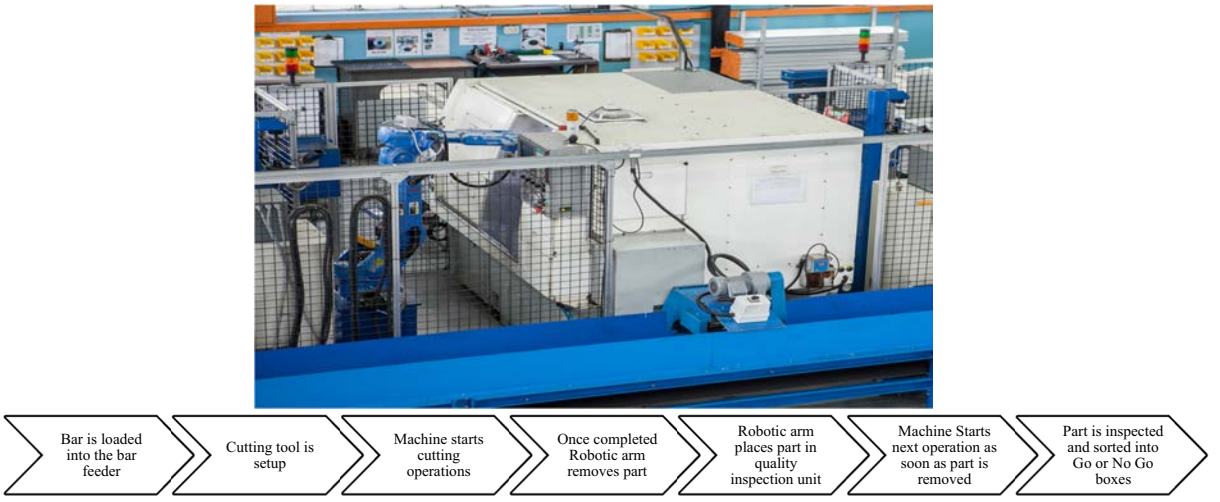

Figure 3 The automated cell (Turning Cell 3) and its process chain

The OEE monitoring software was utilised to collect a large amount of significant data and to accurately compare the automated process to the semi-automated process. The OEE data of the Daewoo 2 and Turning Cell 3 were recorded for four months from the 1st of July 2015 until the 31st of October 2015.[5]. Haldan MES software was used throughout the duration of the study. Haldan MES measures the machine's or cell's availability, performance, and quality in order to visually display all of the loses and potential of the machine or cell [5]. Haldan MES receives signals off the machines Programmable Logic Controller (PLC) to collect the relevant data which is stored in a Structured Query Language (SQL) database on a central server of the factory. The software then converts the relevant data into valuable information that can be displayed throughout the factory. This display enables the workers to identify what is limiting the higher effectiveness themselves [8]. This information can also be utilised to make strategic company decisions and also motivate substantial investments [9].

3. Experimental Results and Discussion

When the OEE data from the semi-automated cell is inserted into the model and compared to the previous OEE or data before the cell was effectively used, the change in profit can be observed in Figure 4.

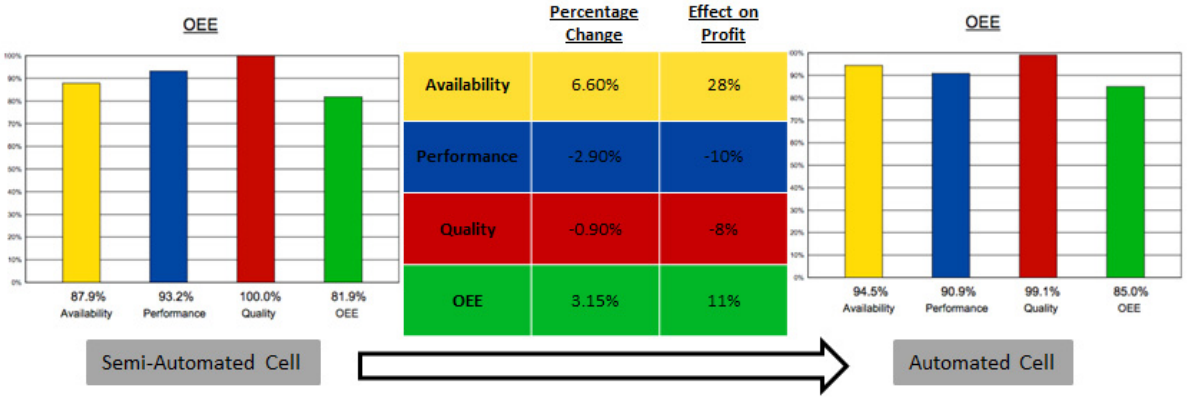

Figure 4 Comparison of OEE data for the Semi-Automated and Automated Cells and the effects on profit

The labour costs of the different cells are compared in Table 4 below.

Table 4: Labour costs for the semi-automated and automated machines

Cell Description	*Worker Skill*	*Labour Cost*	*Labour Costs per Shift (per machine)*
Semi-Automated Cell (Daewoo 2)	Semi-Skilled	R45/hr	R360
Automated Cell (Turning Cell 3)	Un-Skilled	R26/hr	R41.6

Labour costs for the automated cell is considerably less than the semi-automated cell since 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 that needed by the operator of Daewoo 2. A reduction in labour costs of 88.4% results in a profit increase, estimated to be more than 177%. However, in order to achieve this same profit increase without reducing the number of staff, the company would need to increase the quality rate by roughly 20%.

To promote labour in South Africa the effective use of equipment must be prioritized rather than the efficient use of resources. If a 10% reduction in labour is substituted into the model, the result will only be a 20% increase in profit. However, a job could be lost, the work might not be performed correctly without a worker's input, and an annual reduction of 10% in labour is not sustainable for company growth. Nonetheless, to result in a 20% increase profit through equipment effectiveness, an increase of only 4.1% in needed in equipment availability, performance, or quality and only a 3% increase in OEE.

To increase the availability of a machine which relies on manual labour, a solution to the following availability losses should be created: toilet breaks, lunch breaks, tea breaks, sick days, meetings in the office. Two solutions present themselves, one being variable shift times with a substitute labourer who substitutes in for the missing workers, and the other is a robotic substitute which utilises a cageless collaborative robot on wheels from a company such as Universal Robots. Each manufacturing cell would have a different shift start time and workers would all have their breaks at different times. When one worker goes on break another substitute worker or robot would take over their tasks for the duration of the break. Doing this would result in a higher availability of the cell without the large investment into automating the entire process.

4. Conclusion

A semi-automated cell was compared to an automated cell in terms of availability, performance, quality, OEE, labour costs, and profit margins. A higher profit margin was derived from the automated cell due to the higher availability of the cell. The decrease in labour costs also resulted in a higher profit margin for the automated cell. To remain competitive in the global market, OEE should be taken into account when substantial investment in new equipment is required. The model gives an indication as to where a manufacturing company should focus in order to generate the highest profit margin from its machines and labour force. Suggestions were given to promote the use of manual labour to increase the machines availability, which would lead to a higher profit margin for the company.

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