PROCESS IMPROVEMENT FOR THE MANUFACTURE OF EXCAVATOR BUCKET FOR A CONSTRUCTION EQUIPMENT MANUFACTURER

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ABSTRACT

A construction equipment manufacturer procured the SK220 excavator machine from Japan without the bucket. Given the poor quality of outsourced buckets, the company considered manufacturing its own strong and reliable excavator buckets. However, due to Covid 19 pandemic, the company failed to deliver the buckets on time, which affected committed customer orders. The aim of the paper is to pinpoint the bottlenecks within the supply chain and institute some corrective and preventive actions to improve the manufacture of excavator bucket for the construction equipment manufacturer. Capacity planning was conducted to establish the weekly production capacity for the excavator bucket, considering the number of workers and equipment. Root cause analysis was conducted to pinpoint all the waste that characterised the supply chain and significant counter-measures were implemented. The results demonstrated significant productivity improvement, waste reduction and average in monthly sales amounting to R6 250 000.

Keywords: Excavator bucket, Supply chain, Lean, Six sigma

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1 INTRODUCTION

A construction equipment manufacturer is one of the key industrial pillar of South African economy that has a significant economic impact through contribution to agricultural machines, forestry machines, construction machines and providing decent jobs to about 10 000 employees. The new competition is in terms of improved quality, products with higher performance, reduced cost, a wider range of products and better service, all delivered simultaneously [1]. To secure the companies competitiveness, it is necessary to increase the flexibility in the customer order fulfilling process.

The construction equipment manufacturer is the exclusive distributor of Kobelco excavator machines in Southern Africa. The SK220 excavator buckets are manufactured by the company because of customers consider them as strong and reliable. Due to Covid 19 pandemic, the company failed to deliver the buckets on time. The aim of this study is to identify the root causes of inefficiency in the manufacture of excavator buckets and develop measures to ensure excavator buckets are delivered on time.

The Covid 19 pandemic is an infectious disease which was originated in China December 2019, it provoked serious social and economic disruption global. The strong equipment manufacturer was affected due to Covid 19 pandemic. The construction equipment manufacturer was struggling to meet the customer demand, delivery dates and expectation. The late delivery of material at earth moving equipment manufacturer from their suppliers and production constraints has affected the commitment which they already made with customers.

Business organizations have faced huge challenges due to unprecedented disease outbreaks in recent decades. The scope of the challenges faced by these organizations largely depends on the severity of the outbreaks in question. A widespread public health incident such as an epidemic or pandemic can have substantial negative impacts on businesses and supply chains, including reducing their efficiency and performance.

Under the COVID-19 pandemic, the labour resources and supply chain framework are disturbed. The quality of being trustworthy to your customers is significant due to market demand has become more combative and managing supply chain uncertainty is crucial. Covid 19 pandemic has posed a significant challenge for supply chain and logistic execution globally. Multiple national lockdowns continue to slow or even temporarily stop the flow of raw materials and finished goods, disrupting manufacturing as a result.

Time studies will be used to establish daily production capacity of excavator buckets considering number of workers and equipment. Value stream mapping will be conducted to visualize entire process, demonstrates links between operations and to remove non-value-added activities from the process. Cause and effect diagram will be conducted to pinpoint all the wastes that characterised the supply chain and significant countermeasures will be implemented. Implementation of the forecast will also help to set the goal and ensure that the target is achievable.

2 LITERATURE REVIEW

Lean tools have to be applied to increase the SK220 excavator buckets efficiency of the industry. Kanban serves as a tool to control the levels of buffer inventories in the production; in simpler terms to regulate production quantities. When a buffer reaches its present maximum level, the upstream machine is directed to stop producing that part type. Hence, in the manufacturing environment, Kanban are signals used to replenish the inventory of items used repetitively within a facility.

Six-Sigma is described as a data-driven approach to improve business processes by reducing variability, defects and errors in all process that are critical to the customer [2]. Its adoption has now evolved further in service sectors [3]. Six sigma approach improves on time delivery, reduce cycle time for hiring new employers, reducing complaint resolution, and improving the average order fulfilment lead time for sales orders [4]. The approach could be used to improve the company inability to deliver the buckets on time hence the study aim was to pinpoint causes on inefficiency and develop controllable measures.

Roots cause analysis incorporates a broad range of approaches, tools, and techniques to uncover causes of problems, ranging from standard problem-solving paradigms, business process improvement, benchmarking, and continuous improvement [5]. Roots cause analysis is used in different organisations for process improvements of processes and reducing the quality problems. Root cause analysis can be performed with a collection of principles, techniques, and methodologies that can all be leveraged to identify the root causes of an event or trend.

Lean manufacturing defined as a group of tools aimed at minimizing wastes and non-value-added activities in a production setup [6]. It has also been defined as a multidimensional approach that includes Just in Time, quality system, different management practices, work teams, cellular manufacturing, and supplier management in an integrated system to reduce waste [7]. Manufacturing companies are now operating in a highly complex and competitive environment and should engage in Lean thinking initiatives to improve their manufacturing processes. The rate at which new product are being released into the market is increasing. Lean application promotes the production of high-quality products at reduces lead time, thus products are produced at the pace of customer demand.

JIT production can be described as manufacturing the right product at the correct time in its rightful quantity [8]. The JIT principle states the production should be initiated when a customer downstream orders for a product. The benefits realized by the customer pulling the product is that it lowers inventory, throughput time and process variability [9]. The major tools that help JIT construct are pull, Kanban and Production levelling. The pull principles ensure that resources are not dedicated to production before the customer demands for a product [10]. Kanbans are used to initiate the production process and these visual cards or electronic mechanisms carry information about the number of parts to be transmitted to the proceeding process. Production levelling is done to avoid peaks and troughs in the workload of employees thus ensuring that daily production volume is kept constant.

Excavator buckets are digging attachments with teeth that can be fixed to the arm of an excavator. The buckets are controlled by the excavator operator using controls in the cabin. There are different types of excavator buckets that are used depending on where the digging has to be done. Excavator buckets can also be used to move dirt or load dump trucks for transportation to dumping sites. Excavators are used in conventional trenching methods for laying pipelines and also used for digging trial pits for geotechnical investigation [11].

Excavator buckets is a bulk material handling component or specialized container attached to a machine. The bucket has an inner volume as compared to other types of machine attachments like blades or shovels. The bucket could be attached to the lifting hook of a crane, at the end of the arm of an excavating machine, to the wires of a dragline excavator, to the arms of a power shovel or a tractor equipped with a backhoe loader or to a loader, or to a dredge. Excavator bucket is the important part which is responsible for work and excavator bucket life is the very important factor since the bucket may fail to complete its designed life [12]. The major reason behind this failure is its working environment and modes of operations. Excavator buckets are designed to work in worst conditions, situations for long duration of time. During operation, the bucket undergoes excessive stresses, loads, jerks, deformations, and it would be have to be robust enough to withstand such operating conditions [13].

3 METHODOLOGY

After gathering all the necessary problems concerning the current SK220 excavator buckets delays, the project was divided into different phases.

- Phase 1 - The current process was studied and represented in graph forms for simplification and to be able to visualize the impacts as a whole.
- Phase 2 – Conducting of root cause analysis to mitigate factors while also providing the control plan to ensure the project would have positive impact and beneficial to the company
- Phase 3 –Capacity planning were conducted to determine how many excavator buckets can be manufactured a week.
- Phase 4 – Excavator buckets forecast was designed and shared with production department to plan according as per weekly requirement.

4 CASE STUDY BACKGROUND

Given the poor quality of outsourced buckets, the company considered manufacturing its own strong and reliable excavator buckets. However, due to Covid 19 pandemic, the company failed to deliver the buckets on time. The supplied excavator machines that were shipped from Japan to South Africa faced a deficit of excavator buckets which affected committed customer orders. The quality of being trustworthy to your customers is significant due to market demand has become more combative and managing supply chain uncertainty is crucial. The customers were complaining about delays, and hence it was imperative to initiate a project for process improvement.

The information of excavator buckets delivered date versus the required date was obtained from the range of 2020 to 2021. Table 1 represent the bill of materials for the various parts required to manufacture SK220 Excavator bucket.

Table 1: Bill of materials for parts required for Excavator bucket

Part No.	Description	Quantity
TB00595/0	Belly	1
TB00595/13	Side Cover	2
TB00595/04	Middle Cover	1
TB00595/02	Half Round	1
TB00595/05	Lug	1
TB00595/01	Side Plate	2
TB00595/19	Back UO Bar	1
TB00595/16	Fish Plate	1
TB00595/09	Back Rib	1
TB00595/08	8mm Washer	4
TB00595/14	6mm Washer	4
TB00595/07	L Plate	1

TB00595/15	Gasket Plate	2
X4278137	14mm Boss	8
X4197029	Stopper	1
X4218627	3 Hole Boss	3
X4278138	4mm 3 Hole Washer	3
TE02918	Lip Plate	1
TE01741	Pin	2
X4278139	Shim	2
T3053596	Side Cutter	2

The delivery of buckets has been extremely bad, and the organisation struggling to achieve the targets and fulfilling the customer orders.

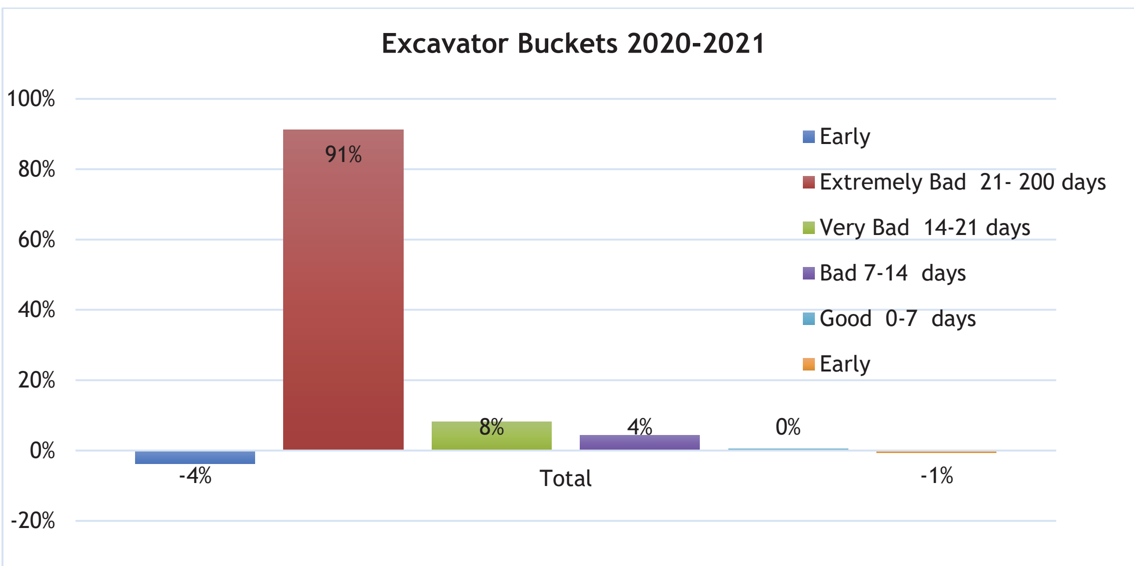

Figure 1: Delivery performance of excavator buckets

From the graph analysis of Figure 1, the indication is that the current process in not working effectively and efficiently in terms of meeting the primary targets. Figure 1 demonstrates that there was that the buckets were never delivered on time, it either delivered too early or too late and this analysis is raising a concerned about currently strategy that used by production department.

Bar graphs represent the poor performance of the production department failing to meet customer expectation. The bar graph analysis highlighted the production constraints which need to be pinpointed to find the root cause of the problem.

5 RESULTS AND DISCUSSION

5.1 Time Studies

The cycle time taken by all the processes involved in manufacturing of bucket is studied and the time taken by them is discussed below. Time study for all the workstations is carried out and the total time is estimated. The time includes the loading, clamping, or fitting and unloading.

TIME STUDY ANALYSIS SHEET — QCL: 145, Rev: 12, Date: 2019/04/11

OBSERVER NAME	Mfundo	CO. NO.	8154	PART/ PRODUCT NUMBER	BN054450	DATE OF STUDY	01/May/22
OPERATOR NAME	Kwazi	CO. NO.	8320	PART/ PROD. DESCRIPTION	EXCAVATOR BUCKETS	STUDY NO.	1
FACILITY NAME	Excavator Buckets	FACILITY ID	PRD20	TASK DESCRIPTION	RHS Nose Box	SHEET	1 TO 1
JIG/ TOOL/ EQUIPMENT/ ASSET NUMBERS		START TIME	08:30	T.E.B.S	1,3	ELAPSED TIME	204,779
		FINISH TIME	15:30	T.E.A.S	1,308	STOPWATCH NO	SW51
FINDINGS & OBSERVATIONS							

NO.	ELEMENT DESCRIPTION	R	OT	ALLOWANCE PER ELEMENT (x where applicable): MANUAL FORCE APPLIED	POSITION: STANDING	POSITION: AWKWARD	POSITION: VERY AWKWARD	ATTENTION TO DETAIL: FAIRLY FINE	ATTENTION TO DETAIL: FINE OR	COMMENTS
1	Oxy Cutting	90	10		x					
2	Removal of burr	80	5		x					
3	Inspection	85	2		x					
4	Rolling of Belly	90	11		x					
5	Inspection	90	2		x					
6	Side and Middle Cover Bending	95	8		x					
7	Machine operation, TB00595 set in ,clamped and drill the hole	75	18		x					
8	Inspection	90	2		x					
9	Right and Left plate drilling and chamfering	95	10		x					
10	Inspection	90	4		x					
11	Assembyly,half round , side plate ,back rib and tag weld	95	10		x					
12	Lug weld	80	10		x					
13	Rib assembly	85	15		x					
14	Adapter assembly	80	10		x					
15	Wedling inside joints and outside	95	25		x					
16	Cover plate and back up bar assembly	100	13		x					
17	Stopper Assembly	95	9		x					
18	Boring	90	8		x					
19	Shot Blasting	80	9		x					
20	Painting	80	15		x					
21	Inspection	90	10		x					

Figure 2: Time studies results for excavator bucket

5.2 Value Stream mapping

Value stream mapping was conducted to analyse how current process operates and to see a process in a holistic view for identifying linkages between information and material flow for the improvement to be implemented.

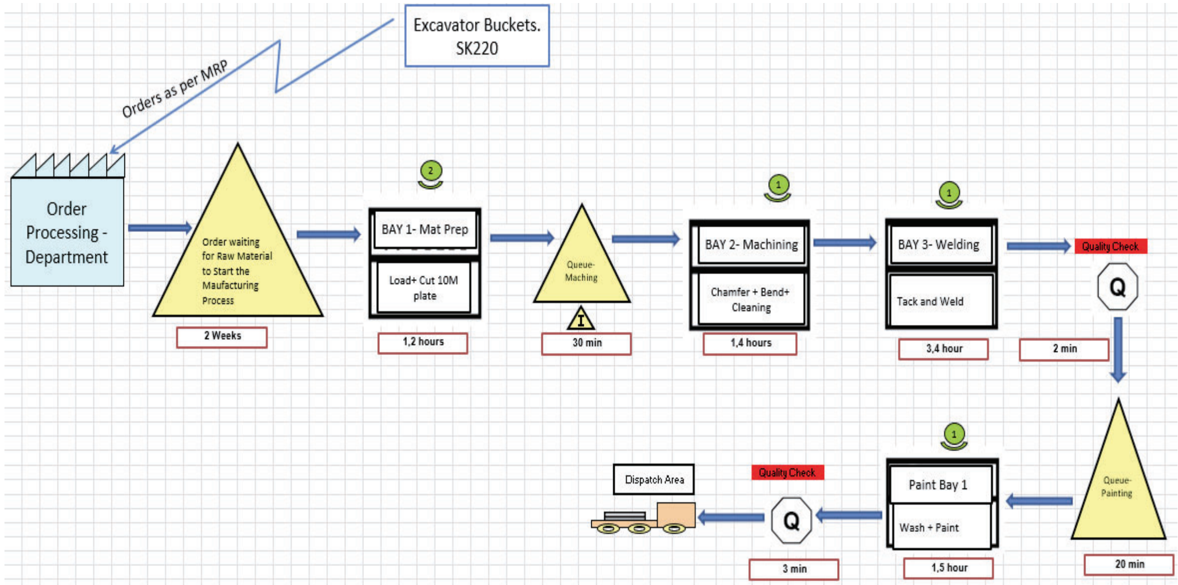

Figure 3: Value Stream Map for Excavator bucket

Figure 3 shows the value stream map for excavator bucket, and it highlighted the area of concern where the waiting time is 4 weeks. The root cause analysis will be conducted below to pinpoint the reason for the delays.

5.3 Cause and Effect Diagram

A cause-and-effect diagram shown in Figure 4 was constructed to identify problems and areas of change of the above value stream mapping. To the right of the diagram the problem is identified as the head of the fish. Then possible causes are identified as the bones of the fish with further causes linked to the main causes.

Facts gathered during preliminary investigation:

- Unskilled operator: could happen the operator requires certain skill or formal education.
- Incorrect material: could happen incorrect tools are used and thereafter rework need to be done which contribute to time delays.
- Not follows customer requirements: specifications or features of the product that are deemed necessary by customers are not being done on time and being done on a later stage.
- Outdated machines and setting time: machine downtime and decrement in production rate due to frequent setup changes being down done and use of old machine which is not effectively and efficient.
- Uncalibrated instruments: Leads to increase down time and unexpected failures as it can affect and damage parts and lead to wastage.
- Incorrect operation and no inspection: inadequate upfront planning which reduced productivity and lot of mistakes being done with inspection.

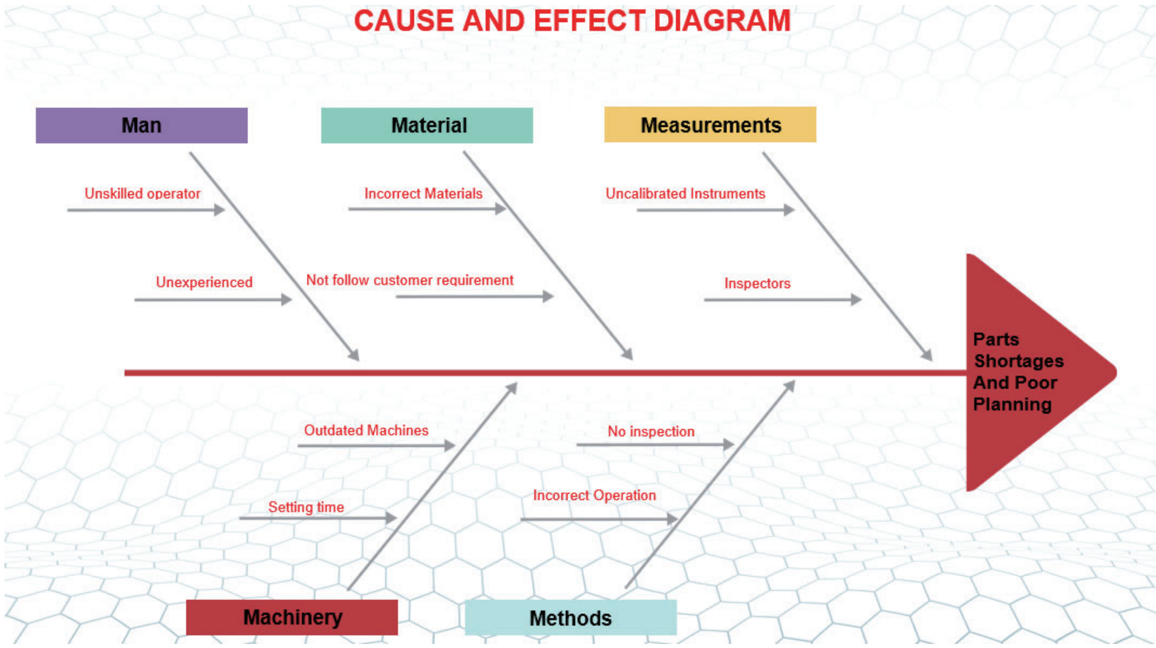

Figure 4: Cause and effect diagram depicting problems with current system

After preliminary investigation and issues being raised it was evident that are great opportunities for improvement of SK220 excavator bucket and many causes that can be addressed. Parts shortages and poor planning are the main course behind the delays of excavator buckets. Shortages were pinpointed as causes of the line stop of more than 3 to 4 days which was attributed to the poor planning. After roots cause analysis, time studies were conducted to plan future of the buckets and to determine how many excavator buckets can be build a week. The production department is operating 40hrs a week and 8 hours a day, upon time study finding it took 5 hours to fabricate a bucket a day. The results shows that only one bucket can be done a day. It was also identified that based on the capacity of production only 5 to 6 excavator buckets can be build a week, that information was used to design the excavator buckets forecast and staggered buckets per week.

5.4 Adjustment of Material Requirements Plans

Table 2 shows a report representing customer orders and required date. The forecast of the customer orders was designed as an improvement to see the customer orders in the 6-month horizons for the material to be order in advance and planned properly as how may buckets we will build per week. The company uses the MRP system to load the customer order requirement for production to react on the demand. The report was run and populated in the excel sheet. The report includes model of the bucket, quantity, order number, required date, serial number and required week for production to react to. The excel pivot table used to make a forecasted based on the information obtained from the report.

Table 2: Report representing customer orders and required date

Model	Order No	Qty	Serial No	Required date	Week
SK220XD-10	M030180	1	JFL3018	25/01/2021	5
SK220XD-10	M030120	1	JFL3012	27/01/2021	5
SK220XD-10	M048530	1	PF4853B	29/01/2021	5
SK220XD-10	M048770	1	PF4877B	01/02/2021	6
SK220XD-10	M048780	1	PF4878B	02/02/2021	6
SK220XD-10	M048860	1	PF4886B	04/02/2021	6
SK220XD-10	M048870	1	PF4887B	05/02/2021	6
SK220XD-10	M048790	1	PF4879B	09/02/2021	7
SK220XD-10	M048800	1	PF4880B	10/02/2021	7
SK220XD-10	M048660	1	PF4866B	11/02/2021	7
SK220XD-10	M048650	1	PF4865B	12/02/2021	7
SK220XD-10	MO48830	1	PF4883C	18/02/2021	8
SK220XD-10	M148850	1	PM4855B	19/02/2021	8
SK220XD-10	M030090	1	JFL3009	22/02/2021	9
SK220XD-10	M030110	1	JFL3011	23/02/2021	9
SK220XD-10	M030170	1	JFL3017	25/02/2021	9
SK220XD-10	M148760	1	PM4876B	26/02/2021	9
SK220XD-10	MO48970	1	PF4897B	03/03/2021	10

5.5 Weekly requirement forecast

Table 3 represent the customer orders in weeks, the customer forecast requirement was staggered as per the capacity planning which was identify by the time studies that only 5 to 6 buckets can be manufactured a week if it happens the demand was more that the capacity planning the requirement were move to the following week. The forecast was shared with production department to have a holistic view of how many buckets required in weeks in order for the production department to confirm in the plan is achievable and also the organisation to commit to the customer.

Table 3: Revised customer orders in weeks

Customer Orders																													
	###																												
Model	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	28	29	30	31	32	33	36	37	38	39	44	45	49	50
SK220XD-10	2	1	4		2	2	2	3	4	3	1		5	1	2	1	3	4	4	4	4	5	4	5	1				
SK260LC-10						1									2	3													
SK300LC-10				3	1	1					3	3		1			2	1							1				
SK380XDLC-10					1	1								3				1							1				
SK850LC-8										1		1													1	1	1	1	2
Grand Total	**2**	**1**	**4**	**3**	**4**	**5**	**2**	**3**	**4**	**4**	**4**	**4**	**5**	**5**	**4**	**4**	**5**	**6**	**4**	**4**	**4**	**5**	**4**	**5**	**4**	**1**	**1**	**1**	**2**

5.6 Ordering Material in Advance

Due to Covid 19 pandemic the lead time of the material increased significantly, the construction equipment manufacturer's sub-suppliers were struggling to get material from their suppliers on time. The construction equipment manufacturer decided to place orders of excavator buckets material in advance to hold the 40 percentage of inventory to ensure that there is enough material to cater for customer requirement because excavator buckets are on demand. The strategy really contributes to meeting the customer expectations.

6 CONCLUSION

In conclusion the aim of the project was achieved because the bottleneck within supply chain was identified, root cause of the problem was pinpoint and new strategy of determining the demand forecast in advance a based on the production capacity was implemented. The weekly requirement forecast improved the planning process, the production department was able to plan accordingly. The organisation experienced significant improvement of excavator buckets after implementation of the new strategy and customer demand were met on time. The organisation benefited from more sales that were made on time, hence more profit was generated. The monthly sales of R12 500 000 were achievable after implementing the new strategies.

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