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Productivity Improvement for a Manufacturing Company by Root Cause Analysis: A Case Study

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Abstract: Manufacturing is the process of converting raw materials into products. The manufacturing process involves a series of activities of planning, design, procurement, production, inventory, marketing, distribution, sales and management. The requirements of the manufacturing process depend on the product offered by the company. These requirements, in terms of facilities, equipment, and production system contribute to the productivity of a company. Productivity is a measure of how efficiently the inputs are converted to outputs. Productivity improvement is a continuous process aimed at doing the right things better by constant improvement on the existing status. In this paper an analysis of the production process was carried out to determine the root cause of the prevailing productivity problem. Solutions aimed at productivity improvement were developed and analyzed. It was found that the losses which were affecting productivity were mainly due to the maintenance practices carried out on the production line equipment. Proper preventive maintenance requires consideration of all the components of preventive maintenance. Machine operators, technicians and production supervisors require necessary training on the use of standard operating procedures and data collection tools to ensure that preventive maintenance is carried out properly.
Keywords: Manufacturing, Productivity, Productivity improvement, Root Cause Analysis

I. INTRODUCTION

A general condition for the continued existence of an organization is that it must provide satisfaction to the customer. The intense global competition and increased demands from stakeholders dictates that companies must strive to improve and optimize their productivity in order to remain competitive (Muchiri et al. 2010). To fulfill customer demands it is necessary to have products in a wider variety, with high quality and several enhanced features. In addition, the products should be delivered with shorter lead times and on time, and at competitive prices. The demand for products and services keeps on increasing hence manufacturing companies are required to increase not only their production potential but also the effectiveness of competition in the global market. According to (Prathamesh et al. 2014), the high rate of increase in demand of production requires the manufacturing industries to increase their production potentials and effectiveness for them to remain competitive.

Manufacturing is a series of interrelated activities and operations involving the design, materials selection, planning, manufacturing production, quality assurance management and marketing of the products of manufacturing industries (CIRP, 1983). Manufacturing should be recognized as a series of production activities of planning, design, procurement, production, inventory, marketing, distribution, sales and management (Katsundo 1996). Manufacturing is a complex activity involving people who have a broad range of disciplines and skills together with a wide variety of machinery, equipment, and tools with various levels of automation including computers, robots and material handling equipment. Due to the large number of interdependent activities with distinct entities, it is therefore regarded as a system. According to (Serope, et al, 2004), manufacturing is the process of converting raw materials into products. The products may be discrete, that is parts or pieces of parts, or continuous products.

Production is the creation of goods and services (Jay et al. 2006).The nature of production in the manufacturing industry is changing at a very fast rate due to the fact that the market demand is less predictable, the time-to-market shorter, and the product life cycle shorter. Production is the process of combining various material and immaterial inputs so as to produce goods or services for consumption (Saari, 2006). It is the process of converting resources into products or services and is usually measured in terms of output per time period (Cliff, 2008).

Productivity is the quantitative relationship between what is produced and what has been spent to produce. It is a measure of the ratio between the output of a process and the input of resources needed for it. Output could be in the form of goods produced or services rendered and may be expressed in physical quantity (where products or services are homogeneous such as number of customers served, quantity of goods produced) or financial value for example sales, production value or value added (SPRING, 2011). Past researches indicate that the performance of a productivity improvement strategy depends on the established maintenance practices (Dilanthi, 2013). The performance would be optimized by the maintenance function or combination of the maintenance practices. Maintenance is a combination of all technical and associated administrative activities required to keep equipment, installations and other physical assets in the desired operating condition or restore them to this condition (Pintelon et al. 2006 cited in Muchiri et al. 2011). The objective of this study was to determine the root cause of the productivity problem and develop solutions for productivity improvement by:

a) Analyzing the production process to determine the factors affecting productivity
b) Determining the root-cause of the productivity problem
c) Developing productivity improvement strategies
d) Implementing the solutions and analyzing productivity improvement

II. LITERATURE REVIEW

Productivity is a measure of how efficiently inputs are converted into outputs. It measures how well resources are used (Nada, 2013). There is fierce competition to attain and maintain the competitive edge in productivity and quality in the global economy hence the planning and managing of productive maintenance activities in industrial and manufacturing organizations should be given high attention (Mathew, 2010). Productivity measures the performance of an organization and can also be used by companies to assess their progress. In general productivity is the ratio of the output to the input of a production system. Productivity expresses the relationship between the quantity of goods and services produced (output) and the quantity of labour, capital, land, energy, technology and other resources used in producing it (input) (Zandin, 2001). Productiveness increases the overall efficiency of a company such that the production capacity is utilized to the optimum level. All resources are used in an effective and efficient manner to get the best possible results.

For a business, the more the products made, the lower the overhead, and the higher the profits. Enhanced production lowers the cost per unit of a product which in turn, resulting in lower prices for better quality, which enhances a business' competitiveness in the market. The lower prices, as a result of enhanced production, give an edge to businesses to sell products at more competitive prices. When the rates are competitive, the business is in a better position to attract more customers and make more sales which is the primary motive of any business organization. Increased production due to efficient utilization of resources leads to a lower cost production resulting in better sales and profits. As the profits shoot up, investors' confidence in the organization increases, the share value of the company rises, and the reputation and goodwill of the organization increases. The business can share a portion of these profits with its employees thus boosting their morale. As a result, their working efficiency tends to increase which in turn, further increases the production of the company.

Productivity is the efficiency in which a company or economy transforms resources into goods to create more from less. Higher efficiency results in better margins through lower costs thus allowing for better compensation for employees, more working capital and an improved competitive capacity. High productivity has the benefit of creating more outputs with the same or fewer inputs. Higher productivity can lead to lower average costs, improved competitiveness and trade performance, higher profits, and higher wages (Sharma, 2008). Productivity is an essential component of an organization's performance hence its productivity improvement contributes positively to an organization's profitability (Kongkiti, 2013).

Production improvement is a never-ending process. It involves repeatedly questioning and requisitioning the detailed working of the process or activity under consideration. Efficiency and effectiveness are often used within the context of productivity. When an organization is able to use its resources in such a way that consumption is less than planned, it is referred to as being efficient. On the other hand, when an organization is able to achieve or exceed its output target, it is referred to as being effective (Kongkiti, 2013). The output of a production process may be improved by increasing the input of resources or changing the process or both. Productivity improvement is the result of managing and intervening in transformation or work processes. The cost of a product or service is the sum of the costs of the resources needed in producing it. The increase of productivity, which is the relationship between output (obtained from production process) and input (used to create output), is an important indicator of the economy and the market value of the firms. (Nuray T., 2010). Productivity can be improved by the economic and efficient use of the input resources. The productivity of a firm depends on how well the input resources to produce goods or services, that is labor, machines, materials, capital, time, space, energy, technology, and others are managed and utilized. These factors can be grouped as internal or external (Sharma, 2008). Internal factors are dependent to the individual organization, such as, environmental factors within the organization (working conditions and incentive schemes), level of mechanism, technical and managerial skills (dependent on the selection, training and number of manpower), use of materials and processes, application of productivity techniques, and type of industrial relations existing. External factors include economic factors such as availability of capital, raw materials, power and market, level of competition, government rules and regulations, policies followed by the government, and sociological factors such as response to change.

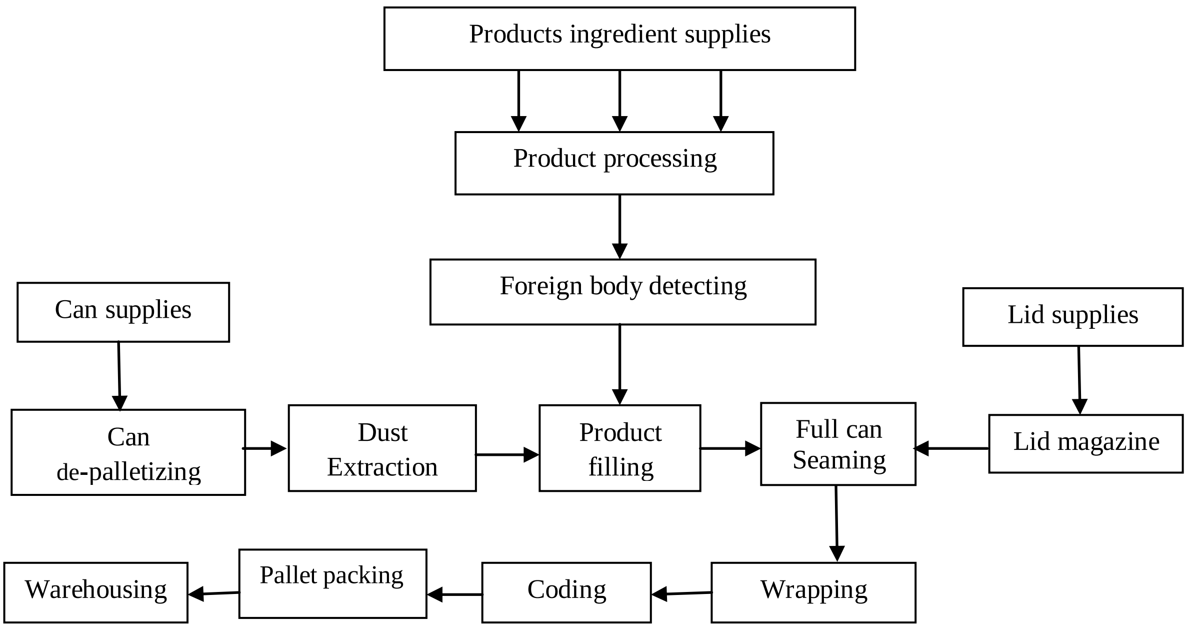
Other measures which affect productivity are:

- Efficiency - Measures the resources expected to be consumed to the resources consumed. It focuses on the input side of the system to determine the degree to which the system utilized the "right" things.
- Effectiveness - Measures what the system sets out to accomplish (objective) with what was accomplished, in other words plan versus actual. Effectiveness is an output measure. The output should be "right" that is, right quality, right quantity, and on time
- Quality - Degree to which the outputs (products and services) from the system conform to requirements or meet customer expectations. The focus is on quality attributes of conformance, performance, convenience, responsiveness, and perceived quality.
- Quality of Work Life - Measures the way that employees in a system respond to the socio technical aspects of that system
- Innovation - Measures the applied creativity of the system. It relates to the design and development of improved products, services, and processes.

III. CASE STUDY

The company presented in this study specializes in the production of beverages, infant nutrition and culinary products which are packed in cans. Productivity was affected by production losses along the production line. The losses were due to content, product quality or as a result of can damages. The main loss arose as a result of can damages. The damage may result directly from can crushing along the process line, or indirectly due to a failure in the filling process thus resulting in either over or under filling of the cans. When this happens, the cans must be opened up and hence a loss.

The material handling process is illustrated in figure 1.3. The product, referred to as seram, is prepared in the product processing department and then supplied in lot bins through a conveyor to the filling machine. The conveyor passes through a metal and other foreign bodies' detector for seram screening. The lot bins empty the product into a hoover in the filling machine (seram filler) for canning. As a can approaches the filling machine, a sensor on sensing the leading edge, triggers the starter for the feed screw. The feed pulses are set depending on the weight that is to be fed into the can. The cans are filled to the required weight and conveyed to the seaming machine (seamer) where they are sealed with lids that are fed to the seamer from a lid magazine. The sealed cans are conveyed to the packing hall where wrapping, coding and pallet packing take place. The finished product is then delivered to the warehouse or shipped The material handling process is illustrated in figure 1.



The recurrent nature of the problem indicated that true causes had not been dealt with hence the need for the symptoms, causes, remedy, and action (SCRA) approach. This was to help in determining:

1. The symptoms and causes in terms of:

a) how, why, when, where and in which way the cans get damaged

b) the contribution of the skills of the worker towards the damages
c) the contribution of the employer or employees in the losses
2. The remedies and necessary action(s) for reducing can damage and control other factors which lead to production losses

To achieve the first objective a flow chart was developed to highlight the areas of loss and a loss tree analysis carried out to establish the production stages which provided opportunities for loss reduction. Primary data was collected and Pareto and 5W1H analysis used to determine the main areas to be addressed for productivity improvement. These areas were the filler, conveyor and seamer stages. Secondary data was collected for the three areas and statistically analyzed to determine the factors affecting productivity.

The second objective was to determine the root cause of the productivity problem. To achieve this and hence develop solution strategies as required of the third objective, inquiries, brainstorming, Ishikawa diagrams, 5Whys charts were used for the filler, conveyor and seamer respectively.

To implement the solutions the system was redesigned to incorporate the improvement measures. Data was collected and statistical analysis carried out to assess the effects of these improvement measures towards productivity.

The company had been collecting data on the volume of can losses per production. The data available however, did not indicate the nature of the can damage and point at which the damage took place. This made it difficult to define the nature of the damage and the measures that could be undertaken to reduce such damage. Data was collected during the production runs to ascertain where the damage occurs and to what extent. The employee was expected to note the following:

1. The nature of damage for example, corrosion tendency, dent(s), improper sealing, over or under filling, defective wrapping, or wrong coding
2. The number of cans affected and the time of occurrence
3. The action taken

IV. DATA COLLECTION AND ANALYSIS

A flow chart (Figure 2) was developed from the material handling process and used to highlight the process stages where losses can occur.

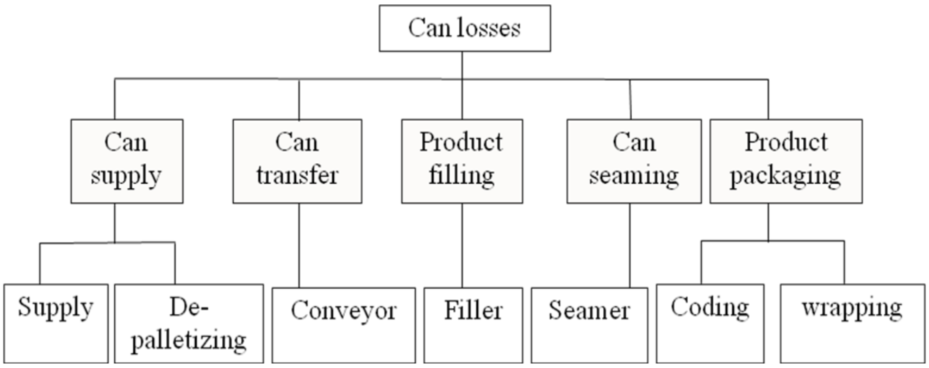


Figure 2 Process stages

Figure 2 shows the stages in the production process, that is, can loading, product filling, can seaming, product packaging, and can transfer, which present opportunities for productivity improvement and hence loss reduction. The factors under consideration as illustrated in figure 2 were categorized into; supply and de-palletizing at the can loading stage, product filling at the seram filler, seaming at the seamer, can transfer on the conveyor, and coding and wrapping during product packaging.

Primary data was collected to establish the productivity of the production line. The company monitors the line efficiency to ensure reliability of the production line by measuring the intensive use of the line assets. The intensity of use of the assets is measured in terms of asset availability, that is, how long the asset is alive and well. Asset availability takes care of speed loss, planned and unplanned stoppages, and waste and rework. Asset availability is the ratio of good production time to actual occupied time. Good production time refers to good running time and good products that are acceptable to the customer being produced, such that there is no can or product loss. Table 1 shows the line productivity and the percentage asset availability before improvement.

Table 1. Line production and percentage asset availability before improvement

Month	Good production time	Actual occupied time	Asset availability, %
January	46.978	89.126	52.7
February	27.475	53.515	51.3
March	24.845	50.027	49.7
April	6.09	10.18	59.8
May	22.125	42.811	51.7
June	32.69	59.76	54.8
July	14.327	24.097	59.5
August	8.764	21.5	40.8
September	38.363	83.073	46.2
October	33.05	71.94	45.9
November	20.277	51.372	39.5
December	38.866	91.501	42.5

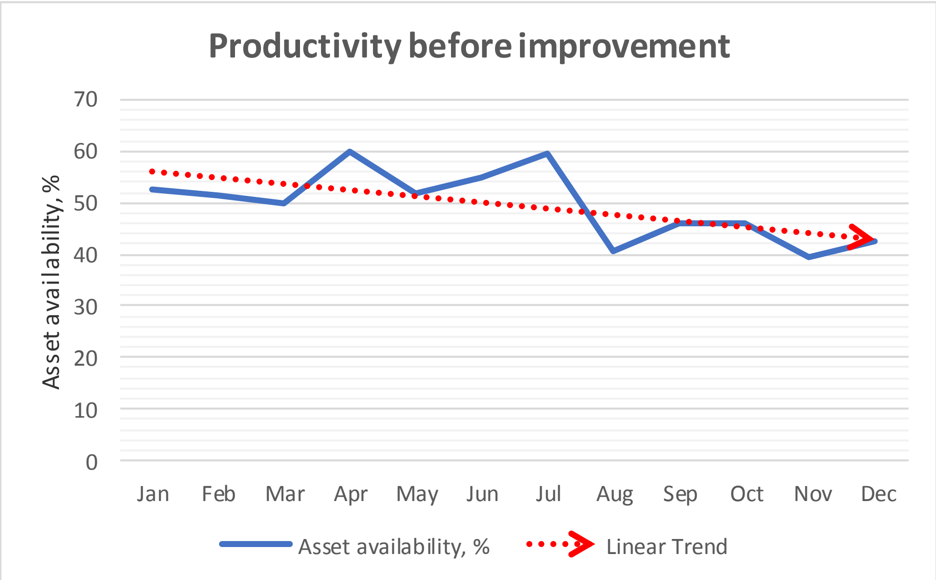


Figure 3. Production line asset availability before improvement

Figure 3 shows a decreasing trend in the productivity of the production line. The average asset availability of the production line was 49.5 percent. The continued drop in asset availability implied increased can and product losses.

For preliminary analysis production data was collected and analyzed to prioritize the areas where improvement was required in order to enhance productivity on the production line. As a measure of the existing situation, data was collected using the data collection sheets and checklists at the stages for different shifts. The data collected was then validated by considering reports taken on random days and shifts. Table 4.2 shows the total percentage average time in unplanned stoppages.

Table 2 Total average losses

	De-palletizer	Filler	Seamer	Conveyor	Packaging
Total Average loss, %	0.5	7.7	14.7	3.7	0.8

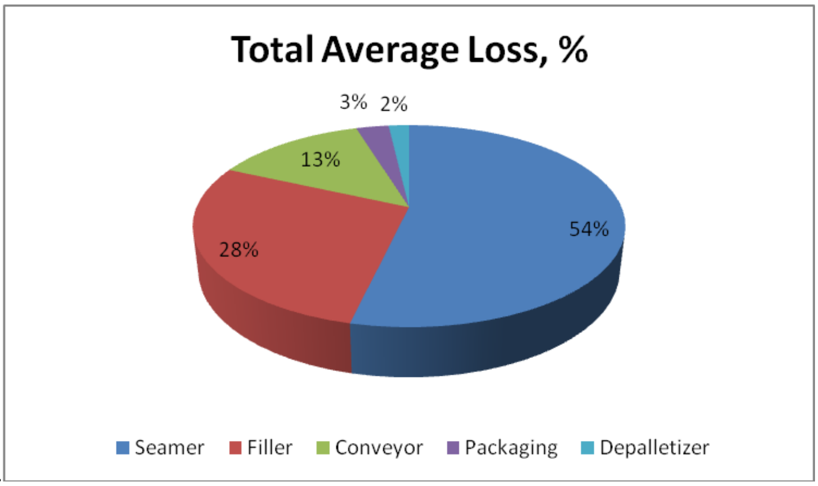


Figure 4. Percentage time loss due to unplanned stoppages

Figure 4 shows the relative proportions for the total average losses. The percentage proportions were used for analysis. A Pareto analysis was performed to identify the vital few loss areas to concentrate on in order to reduce losses and hence improve productivity (figure 5).

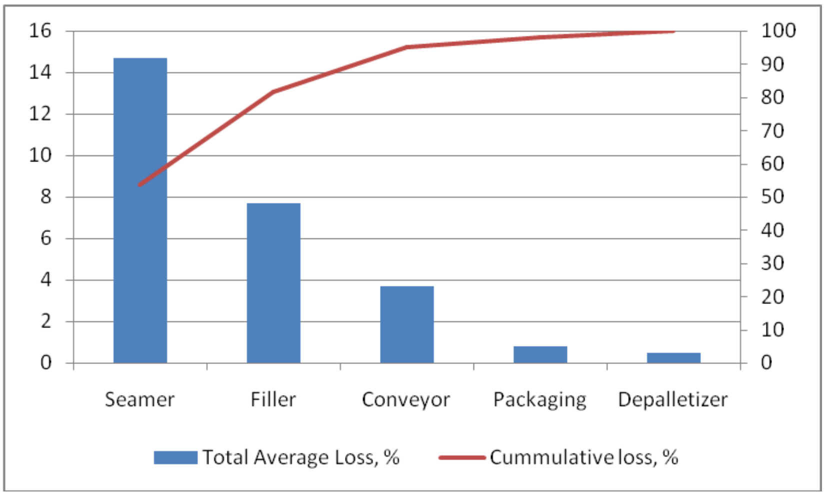


Figure 5. Pareto analysis for improvement areas

The seamer has a proportion of 53.6%, the cable conveyor 28.1% and the filler 13.5%. The three areas of the filler, seamer and conveyor contribute 95.2% hence focus was concentrated on the three stages as priority areas for productivity improvement. The data was further analyzed to determine the contribution of the employees (operators), shifts and process stages to the production losses.

The 5W 1H method was used, as shown in figure 6, to determine the correlation of the productivity problem to the operators in the three areas.

WHERE Location?	**WHAT** Problem?	**HOW** How does it happen?	**WHICH** In which way?	**WHEN** Process at occurrence?	**WHO** Correlate to or vary with operator?
Filler	High can losses	Weight variations	Under/overfill, quality	Filling	No
Conveyor	High can losses	Jams/derailments	Dents	Cans transfer	No
Seamer	High can losses	Seamer damages	Poor seams, dents	Seaming	No

Figure 6 5W1H analysis

The operations of seram filler, cable conveyor and seamer were considered. As a measure of the existing situation, data was collected using the data collection sheets and checklists at the stages for different shifts as shown in table 3. The data collected was then validated by considering reports taken on random days and shifts.

Table 3 Can losses before improvement

PRODUCTION RUN	SHIFT RUN	ACTUAL OUTPUT	CAN LOSSES		
			CONVEYOR	FILLER	SEAMER
RUN 1 EXPECTED OUTPUT: 1800	SHIFT A	434	7	4	126
	SHIFT B	31	12	6	164
	SHIFT C	635	5	10	67
RUN 2 EXPECTED OUTPUT: 1800	SHIFT A	960	7	2	87
	SHIFT B	1027	1	7	23
	SHIFT C	788	12	17	104
RUN 3 EXPECTED OUTPUT: 1800	SHIFT A	464	11	22	98
	SHIFT B	237	5	6	67
	SHIFT C	634	7	9	87
RUN 4 EXPECTED OUTPUT: 1000	SHIFT A	455	5	12	62
	SHIFT B	350	14	7	23
	SHIFT C	142	6	2	17
RUN 5 EXPECTED OUTPUT: 1100	SHIFT A	278	13	4	90
	SHIFT B	325	18	11	57
	SHIFT C	405	7	16	89

The data collected was analyzed to establish the contribution of the shifts and production process stages to the productivity problem.
The loss of cans was analyzed against the production runs for the shifts as shown in table 4. To check whether the shift had any effect on the can losses, a chart (figure 7) was plotted.

Table 4 Can losses per production run for each of the shifts

Production Run	Can losses		
	Shift A	Shift B	Shift C
1	137	182	82
2	96	31	133
3	131	78	103
4	79	44	25
5	107	87	112

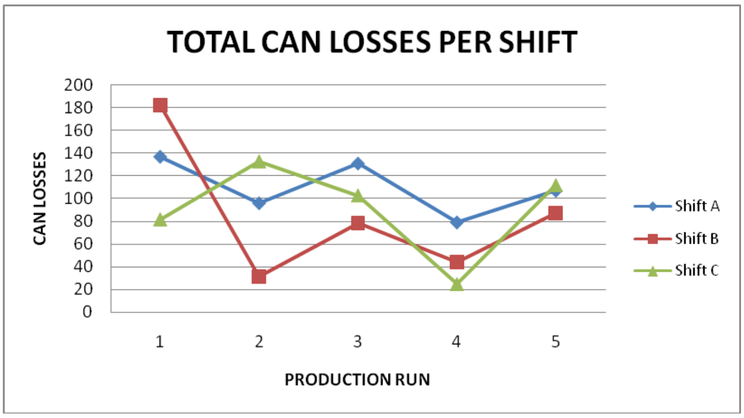


Figure 7 Total can losses per production run per shift

It was observed that the losses for shift C did not follow the same pattern as those for shifts A and B. Shift C is the night shift. It was established that the night shift faces some few challenges unlike the morning and afternoon shifts. While day shifts operate in the presence of managers, supervisors and technicians the night shift suffers less support with only one technician on duty. The choice of technician on duty has a bias on electrical rather than mechanical skills.

The losses as shown in table 5 were considered for the shifts at each stage. A chart for the can losses against the production stages was plotted (figure 8) for the three shifts.

Table 5 Total Can losses per shift per production process stage

Shift	Seamer	Cable Conveyor	Filler
Shift A	463	43	44
Shift B	334	50	38
Shift C	364	37	54

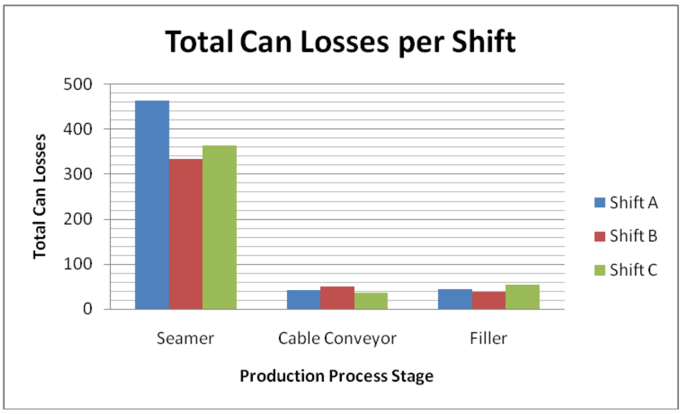


Figure 8 Total can losses per shift

The chart (Figure 8) indicated that the seamer was a major contributor to the can losses. This required further analysis.
An analysis for the total can losses as tabulated in table 6 for the stages was carried out. A chart for the total can losses was plotted (figure 9) for the three production stages.

Table 6 Total can losses per production stage

	Seamer	Filler	Conveyor
Total Can Losses per stage	1161	135	130
Cumulative Frequency	81.4	90.9	100

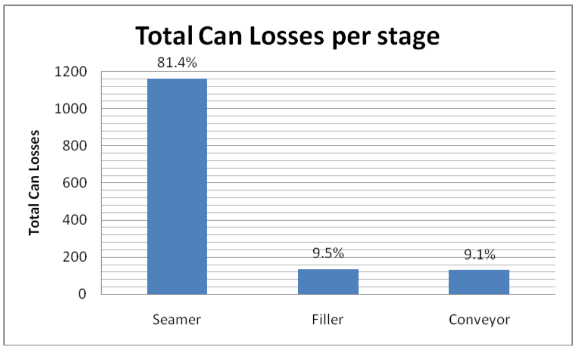


Figure 9 Total can losses at seamer, conveyor and filler

V. ROOT CAUSES ANALYZES AND SOLUTIONS

The Cause and Effect (Ishikawa) diagram was used as a quality improvement tool to find the root causes at each stage. The various causes determined from the Ishikawa diagram were subjected to the Five Whys technique to establish the root causes and develop the respective solutions. By repeatedly asking why, the cause was traced back to the original cause (root cause). Root cause analysis was carried out at each of the stages of the conveyor, filler and seamer. Once the root cause was established, a solution or course of action was recommended to solve each problem.

Conveyor

Various possible causes were considered using the cause and effects (Ishikawa) diagram. The identified possible causes were subjected to the Five Whys technique to establish the root causes and hence the solutions. The results of the why-why analysis for the conveyor is shown in table 7.

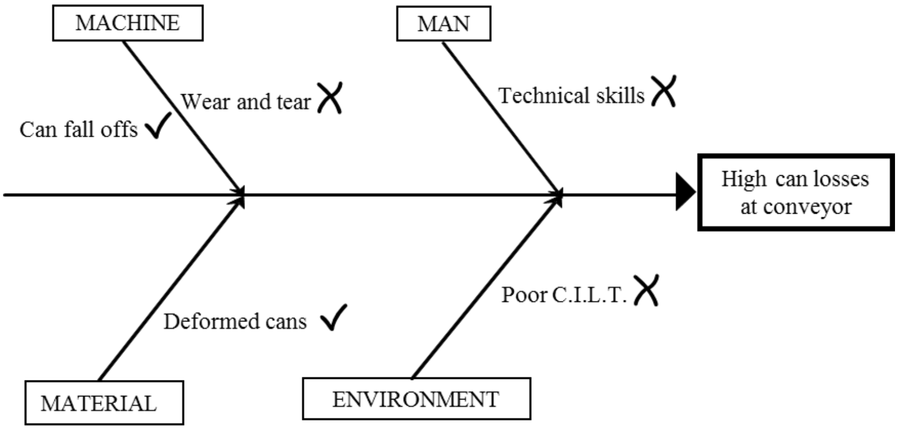


Figure 10 Ishikawa diagram for the conveyor losses

Table 7: Results of the Why-Why analysis for the conveyor

Problem	Root cause(s)	Solution/ action strategy
Deformation of cans while on conveyor	Design of the conveyor line	Redesign the line: 1) Synchronize the speeds of seamer and filler 2) Install sensor/ switch to be shared by both seamer and filler 3) Modify exit twister to allow enough time for the seamer to stop
Cans fall off from conveyor	1) Operator laxity 2) Low technical knowledge	Operator to be strictly at station when conveyor is running Provide One Point Lessons (OPLs), checklists and training

Poor flow of cans resulted in a blockage hence creating a back pressure of cans and consequently some cans could fall off. The speeds of seamer and filler were synchronized. Sensors were installed at the end twister to stop seamer in case of blockage. The exit twister was modified to allow enough time for the seamer to stop. Line operators are to be more vigilant to ensure smooth can travel devoid of jamming and obstruction. One Point (or Single Point) Lessons (OPLs), checklists for the conveyor were created and training provided.

Filler

The cause and effects diagram was used to identify the potential causes. The why-why analysis was used to analyze and identify the root cause(s) and the possible solutions for the filler. Table 8 shows the outcome of why-why analysis for the filler.

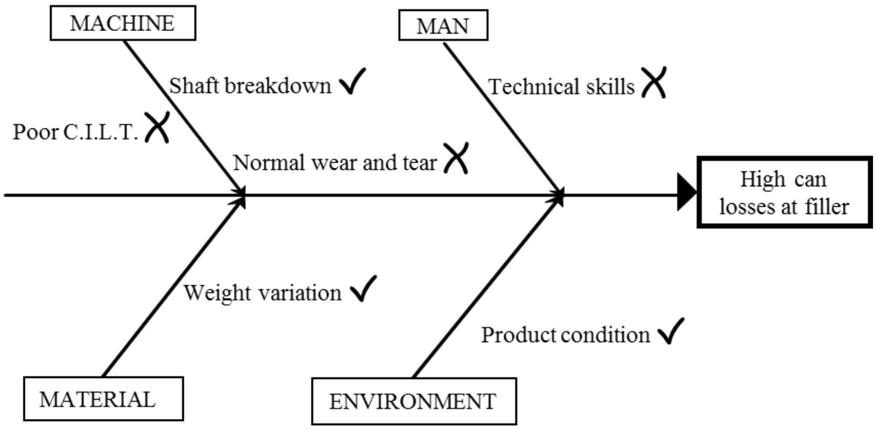


Figure 11 Ishikawa diagram for the filler

Table 8: Outcome of the Why-Why analysis for the filler

Problem	Root cause(s)	Solution/ action strategy
Weight variation	Nature of product	Constantly check the weight before seaming stage
Product condition	1) Incorrect AHU setting 2) AHU not adequately controlling room humidity	1) Provide OPL and training 2) Validate AHU settings according to season 3) Install sensor 4) Run performance checks
Shaft breakdowns	Modification carried out without Standard Operating Procedures (SOPs)	Provide SOPs, and train technicians and operators

A modification had been carried out on the machine without using standards. No lock nuts were used which accelerated the tear and wear. The shaft became loose and sheared with time. The shear can eventually lead to the shaft breaking up resulting in a sudden machine stoppage since there would be loss of grip and consequently the roller heads become free.

The drive shaft was replaced, and the standard operating procedures provided. Sensors were installed to stop filler and hence prevent product loss in case of a failure of the AHU. The operators and technicians are to be trained on the standards.

Seamer

The seamer contributed 81.4% of the can losses. The seamer was a major concern due to the rate of can damage and the consequent losses due to downtime. The quantity of can damages and the frequency of occurrence were very high. The Equipment Availability analysis (EA) was carried out for the seamer.

The Equipment Availability indicator is expressed by the equation:

$$EA_e = H_c / H_t, \text{ where}$$

EA_e is the equipment availability, H_c is the number of hours the equipment is available to run at capacity, and H_t is the total number of hours during the reporting period

The equipment availability indicator for the seamer, EA_{seamer} was 0.8, implying that the seamer was 80% available. This is below the industrial corporations' benchmark figure of 96% (Dhillon, 2002). Further analysis was carried out on the seamer using the Ishikawa diagrams shown in figure 12. Table 9 shows the results the why-why analysis used to analyse and identify the root cause(s) and the possible solutions for the seamer.

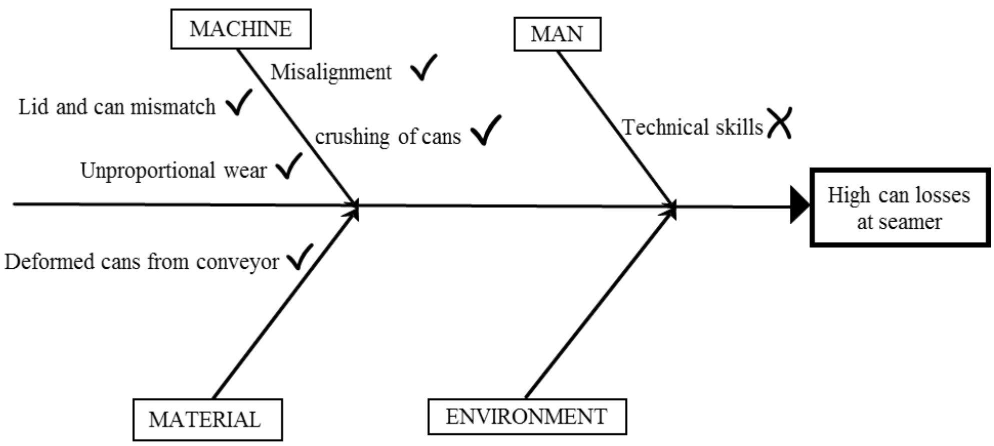


Figure 12 Ishikawa diagram for the seamer losses

Table 9 Why-Why analysis results for the seamer

Problem	Root cause(s)	Solution/ action strategy
Crushing of cans	Delivery from the supplier Lack of SOPs	1) Liaise with the supplier 2) Sort lids before loading into magazine 1) Create SOPs, OPLs and provide training 2) Tighten the lid release mechanism
Un-proportional wear of parts and misalignment	Poor maintenance practice	1) Overhaul to restore basic conditions 2) Provide training on SOPs 3) Create checklist for parts prone to wear and tear

Lid and can mismatch	Lack of standard on cleaning after can crushing	1) Create OPL for cleaning after can crushing 2) Create checklist for C.I.L.T.

It was observed that proper maintenance practice was not carried out despite the maintenance, repair and service jobs being undertaken. There was un-proportional wear on the chucks and rollers, and this was addressed by making respective adjustments, to accommodate the wear, during the maintenance and repair works. With time, as these adjustments were made, the machine eventually lost its basic settings. Any repair and maintenance would serve for only a short while and another problem would arise. Some consequences that arose out of this were misalignment of elevators take off, lower and upper tables, lifter unit to seaming chuck relationship; loss of head adjustments; loss of smooth flow of cans due to affected in-feed twister and feed rail, seamer tangential profile guides, and turrets; loss of sensor sensitivity, and wearing out of the runway adjusting screw threads. The operators and technicians at this station have the necessary skills. There are standards in place, and they are clear and available. A key issue was that operators and technicians had not been trained on the standard.

A comprehensive corrective maintenance action was required. An overhaul of the seamer was carried out to restore the seamer basic conditions. New bearings, chucks and seaming rolls were fitted. A sensor was installed at the discharge station. A checklist was developed for the seamer parts and components that are prone to tear and wear easily. Training for operators and technicians on Standard Operating Procedures (SOPs), One Point Lessons (OPLs) and checklists was planned.

VI. ANALYSIS OF PRODUCTIVITY IMPROVEMENT SOLUTIONS

The data shown in table 10 was collected after the productivity improvement solutions were implemented. Comparison of the total can losses in table 11 was carried out for the periods before and after the maintenance activities. A chart for comparison of can losses before and after action was plotted as shown in figure 13.

Table 10 Can losses after improvement

PRODUCTION RUN	SHIFT RUN	ACTUAL OUTPUT	CAN LOSSES		
			CONVEYOR	FILLER	SEAMER
RUN 1 EXPECTED OUTPUT: 1800	SHIFT A	1361	1	4	23
	SHIFT B	1428	2	1	12
	SHIFT C	1379	1	3	7
RUN 2 EXPECTED OUTPUT: 1800	SHIFT A	1817	4	3	19
	SHIFT B	1302	7	2	23
	SHIFT C	1476	9	7	34
RUN 3 EXPECTED OUTPUT: 1800	SHIFT A	1535	5	2	15
	SHIFT B	1210	8	6	32
	SHIFT C	1190	5	2	21
RUN 4 EXPECTED OUTPUT: 1000	SHIFT A	1598	1	5	7
	SHIFT B	1100	3	8	13
	SHIFT C	1060	1	4	9
RUN 5 EXPECTED OUTPUT: 1000	SHIFT A	992	4	3	17
	SHIFT B	1003	3	2	22
	SHIFT C	987	2	1	10

Table 11 Total can losses before and after improvement

	Seamer	Filler	Conveyor	Total can losses
Before improvement	1161	135	130	1426
After improvement	264	53	56	373

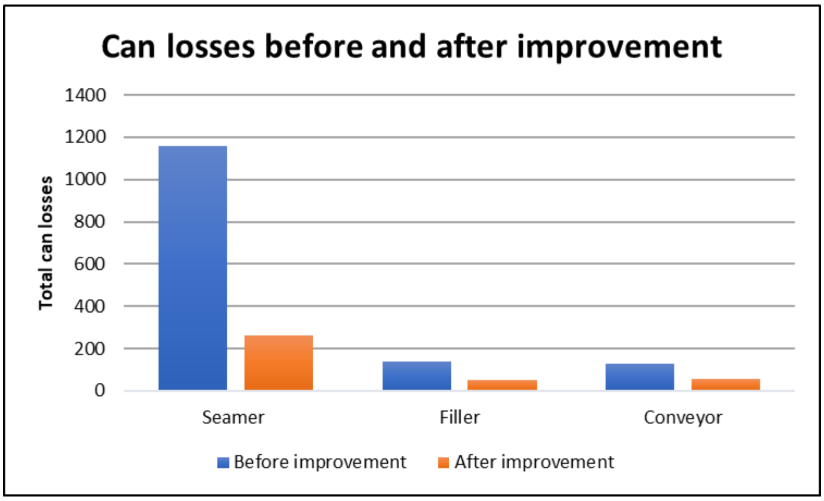


Figure 13 Total can losses before and after improvement

The total can loss was reduced by 73.86%. This indicates the impact of proper maintenance of production equipment and which can be enhanced through availability of standard operating procedures and provision of training. Line production through the year was collected to assess the impact of the improvement on the line productivity.

Data for the year was analyzed and tabulated in terms of good production time against actual occupied time as shown in table 13. Good production time refers to good running and good product that is acceptable to the customer (no can or product loss).

Table 12 Line production after improvement

Month	After improvement		
	Good Production Time	Actual Occupied Time	Asset availability, %
January	9.778	18.982	51.5
February	34.98	61.80	56.6
March	11.636	20.75	56.1
April	24.876	36.933	67.4
May	29.142	37.327	78.1
June	30.345	44.27	68.5
July	26.494	39.825	66.5
August	27.77	34.473	80.6
September	28.296	37.662	75.1
October	27.54	36.05	76.4
November	193.80	265.39	73.0
December	74.92	102.15	73.3

Data analysis for the whole production line indicates a continued productivity improvement with the average asset availability increasing to 68.6 percent. Data taken over the two-year period confirmed this trend. The asset availability rose, from below 50% to over 70% after undertaking the improvement measures.

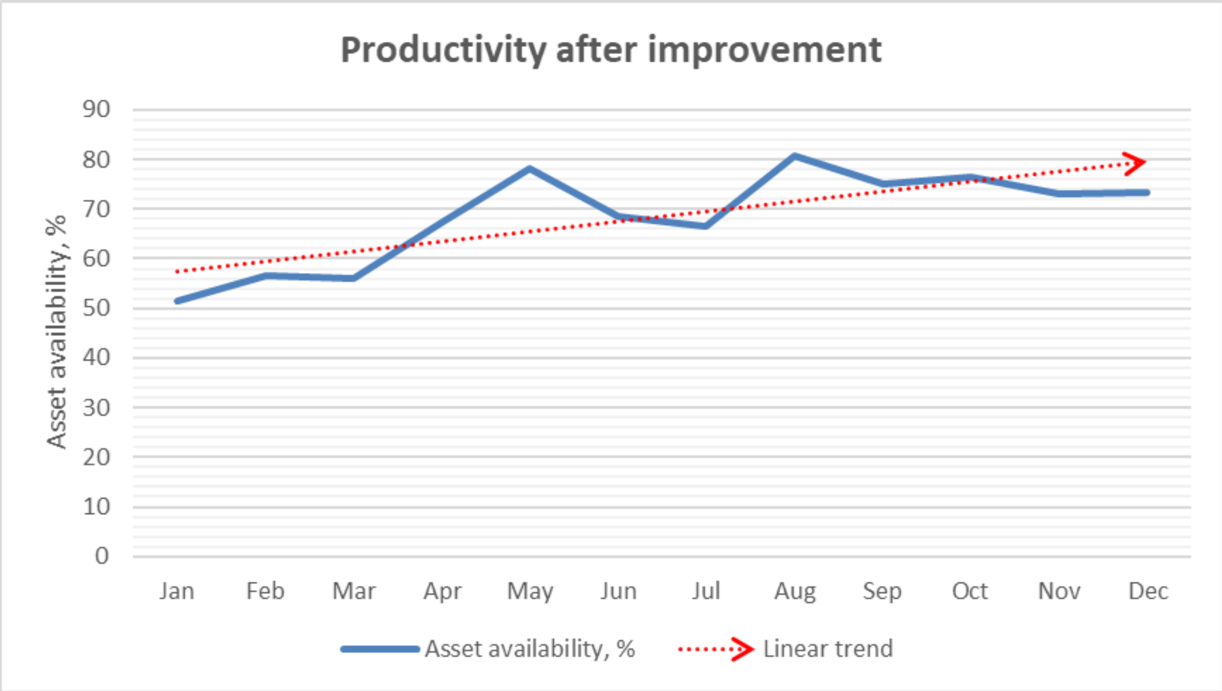


Figure 14 Line productivity after improvement

The following deductions can be made from the results observed:

- Develop and avail Standard Operating Procedures (SOPs) and One Point Lessons (OPLs)
- Train production supervisors, technicians
- Follow Standard Operating Procedures (SOPs) when carrying out maintenance activities
- Maintain good records of first and second level data
- Enhance speed management

VII. CONCLUSION AND RECOMMENDATIONS

The conveyor, filler and the seamer were identified as the priority areas and data was collected and analyzed. It was established that night shifts face some challenges unlike the other shifts. The seamer was the major concern, contributing 81.4% of the can losses. Further analysis was carried out on the seamer through brainstorming and Ishikawa diagrams. Proper maintenance was not carried out despite the maintenance, repair and service activities undertaken.

Standard operating procedures (SOPs) were either not provided or available and this affected the maintenance process. The operators and technicians also lacked training on the standards. Proper preventive maintenance practice was not carried out, since all the components of PM, that is, Inspection, Servicing, Calibration, Testing, Alignment, Adjustment, and Installation were not considered. Production supervisors, technicians and machine operators need to undergo training and coaching sessions. Comprehensive corrective maintenance was carried out and the operations monitored. The asset intensity of the production line was observed to improve from below 50% and rose to above 70%. The target asset intensity was 75%.

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