# IMPROVEMENT OF A BEER PACKAGING LINE THROUGH PARETO ANALYSIS, ROOT CAUSE ANALYSIS AND STATISTICAL TRACKING

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## ABSTRACT

It is imperative for players in the beer industry to increase efficiency continuously to stay ahead of the competition. The prevailing performance of a beer packaging line in terms of engineering stops at the case study plant was below the target set by management, and therefore improvements were vital. This paper outlines the improvement of a beer packaging line through Pareto analysis, root cause analysis, and statistical tracking at a beer producer. The procedure commenced with gathering the data for the line and conducting a Pareto analysis on beer loss. It was found that bottle conveyors' downtime was caused by bottle breakages which was also resulting in beer loss. A root-cause analysis was conducted for high filler fallen bottle stoppages and possible solutions for process improvement were then formulated and the best solution was implemented. T-Tests were finally deployed as a means of statistical tracking and the results demonstrated a significant process improvement.

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## 1 INTRODUCTION

The current beer market is heavily characterised by an endless change in consumers' preferences [1, 2]. As a result, the beer production industry is extremely competitive leading to participation by almost all nations in the world. The beer industry thrives for sustained consumer satisfaction by committing to quality and process enhancement to augment unsustainable operating costs and boost competitiveness [3]. The market in South Africa has experienced a surge of smaller and independent breweries, who sell locally and have direct contact with consumers. Therefore, it is imperative that bigger players in the beer industry continuously increase their efficiency and reduce operational costs through the production of more products while utilising fewer resources if they are to remain competitive. Waste during beer production increases production costs and impacts efficiency. It is against the backdrop of rising competition that the case-in-point brewer must ascertain the root causes of beer loss during the packaging process and institute cost-effective measures on the packaging line to reduce or eradicate the loss. This paper adopts a focused improvement approach to improve a beer packaging line through the deployment of Pareto analysis, root cause analysis, and statistical tracking.

## 2 LITERATURE REVIEW

The beverage industry is one of the world's largest industrial sectors that contributes significantly to national economies [4]. Therefore, the brewing sector holds a strategic economic locus and creates a lof of jobs in these economies. Tsarouhas [5] argued that there is a strong connection between manufacturers and their customers who demand that the products should be delivered on time with the proper quality, basing on market requirements. Modern industrial systems would apply automation such as conveyor systems and other advanced technologies to produce quality goods in the right quantities. This study will focus more on the beer packaging line since the statistical analysis will be carried out using data from this specific process.

A beer packaging line can be described as indicated by Groover [6] as a set of mechanised and automated devices that perform various assembly tasks in a fixed sequence of assembly steps on a particular product being produced in bulky quantities. A beer bottling facility would be characterised by a filling machine with several filling positions, and each filling device would supply the liquid filling material to a specific filling position [7]. A predetermined volume of beer would be injected into the bottle to a predetermined level of beer by a filling device, and the filling process will terminate when the beer has reached the predetermined level in the bottle. Conveyance systems such as conveyors may be used to move bottles between stations [7].

A typical beer packaging line for returnable bottles as shown in Figure 1 is characterised by the movement of palletised crates from the warehouse, depalletisation, decrowning and empty bottle unpacking, bottle and pallet cleaning, bottle filling and crowning, labelling, and palletising [8]. The packaging line consists of four machines that include the filling/crowning machine, conveyor belt, packing machine and palletizer. It is a subsystem of the beer production line and the rotary filling/crowning machine is fully automated and the transmission system is driven by motors, through a synchronization control system. A typical filling/crowning system is characterised by a hopper, which is a container for parts, parts feeder for removing crowns from the hopper, selector and orientor mechanism to assure that crowns are in proper orientation for capping, feed track and escapement and placement devices [6]. The material handling system is characterised by movement of empty bottles to the machines for washing, filling, crowning, pasteurising and labelling ensuring their removal from the machine after their filling [5].

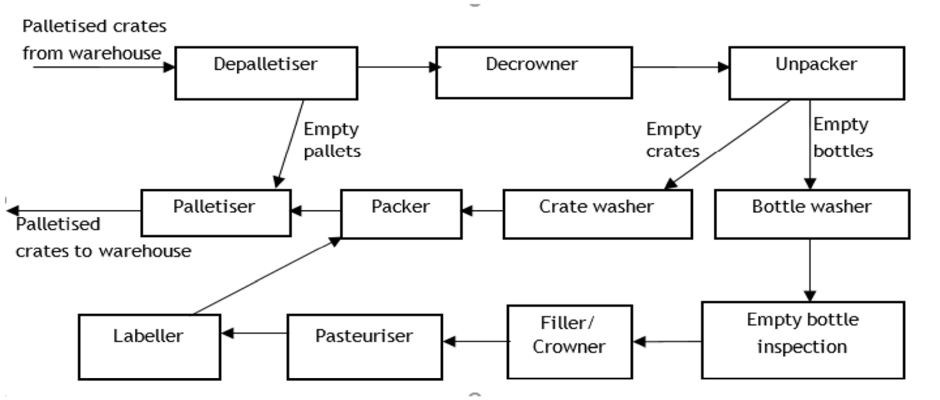


**Figure 1: Flow diagram for beer packaging operations,** (Adopted from [8])

An organisation must use a maintenance policy that is tailored to meet its maintenance requirements for its packaging line. As posited by [9], high food standards characterise the food industry where production is accomplished by advanced and complex equipment that should operate optimally to meet the demand. Hence, unanticipated failures would lead to emergent stoppages in production and non-compliance with production plans, and that should be avoided. This study focused on the problem of poor packaging line reliability that was manifested as bottle conveyors downtime which was caused by bottle breakages which was also resulting in beer loss. Tsarouhas and Arvanitoyannis [5] conducted a reliability analysis for packaging of beer production and used field failure data to assess the operational management for the beer packaging line. They found that the currently applied maintenance policy of the beer filling and crowning machine was corrective maintenance that was characterised by recognition, isolation, correction and operation checkout. Isolation can be described as localization and diagnosis of maintenance problem, while correction is characterised by disassembly, removal, replacement, reassembly and adjustment.

The Deming Cycle or Plan-Do-Check-Act (PDCA) is a four-step iterative technique for continuous improvement, which is used to improve organizational processes and to solve industrial problems [10]. The beer packaging process efficiency can be improved by exploiting the Deming PDCA Cycle. The planning phase is characterised by the identification of the goal of the improvement project, prescribing the optimal metrics and developing a plan of action. The Do step is characterised by the execution of the plan. The Check step is aimed at monitoring the outcomes to assess the validity of the plan and establish signs of progress or areas for improvement. The Act phase closes the cycle by embracing the lessons that were learnt from the project. These four steps are replicated as part of a continuos improvement process in an organisation [11].

An Ishikawa or cause-and-effect diagram is a Kaizen tool that can be used to identify and display possible causes of a particular problem [12]. Matende [13] conducted a study to optimise packaging operations for a beer production line by using lean manufacturing tools to identify bottlenecks and determine line efficiency loss. An Ishikawa diagram was used to identify root causes of the problem, and palletiser and depalletiser machines were identified as bottlenecks. Adopting a new preventive maintenance strategy and implementation of line balancing techniques resulted in waste reduction for the packaging operations [13].

## 3 RESEARCH APPROACH

A systematic methodology was deployed to reduce downtime of bottle conveyors which was caused by bottle breakages and thereby resulting in beer loss for the packaging line. The first step in the methodology was problem definition, which was characterised by comprehending the problem by formulating the problem statement, understanding the project scope, and establishing whether the problem was measurable. It is vital to explicitly understand the problem and comprehend its scope since failure to properly define or fully appreciate the scope of the problem would yield a mismatch between the problem and proposed solution, thereby resulting in solutions that do not satisfactorily mitigate the problem at hand. The problem was found to be bottle conveyors downtime which was causing bottle breakages and resulting in beer loss. The project scope embraced all bottle conveyors from the movement of palletised crates of empty bottles from the warehouse to the movement of palletised crates of filled bottles to the warehouse. Using the data for the SAP or data warehouse system, the problem was found to be measurable and was calculated by using the following formula:

*Downtime = Filler stoppage time until the filler runs at full speed*

The second step embraced gathering the data about the problem and conducting a Pareto analysis to identify the machines or processes that contributed to high bottle conveyors downtime that was causing bottle breakages. The third step in the methodology was to describe the problem accurately after gathering all the data related to the problem and drawing a fishbone diagram for root-cause analysis. Through visual observation, it was vital to verify if the system was operated according to the prescribed standard operating procedures, and as well as to establish if the standard maintenance procedures were being observed.

The fourth key step in the methodology embraced identifying process improvements by applying the verifications that were chosen for exploration in step 3. The fifth step in the methodology was characterised by selecting the best possible solution and implementation of the possible solutions through the Deming's PDCA cycle. The sixth key step in the methodology embraced close the loop and developing a maintenance program to reduce bottle conveyors downtime. Lastly, the results were analysed after the implementation of the Deming's PDCA cycle, and the actual and target values were tracked to verify if there were improvements in reduction of bottle conveyors' downtime figures.

## 4 DEFINITION OF PROBLEM AND IMPLEMENTATION OF SOLUTIONS

### 4.1 Problem definition

Historical data on the performance of the beer packaging line was retrieved from performance records. Data was drawn from the SAP ERP system for the brewery and Figure 2 shows a summary of engineering stops for the packaging line. Major engineering stops of above 7000 stops per year were noted for the bottle washer, bottle filler and bottle conveyor. The crowner, palletiser and crate washer experienced the minimum number of line stops per month. In this study, less attention was paid to the bottle washer since the empty bottles did not affect beer loss. The filler and the bottle conveyor were considered for the study since bottle conveyor stoppages affected the filling machine as well.

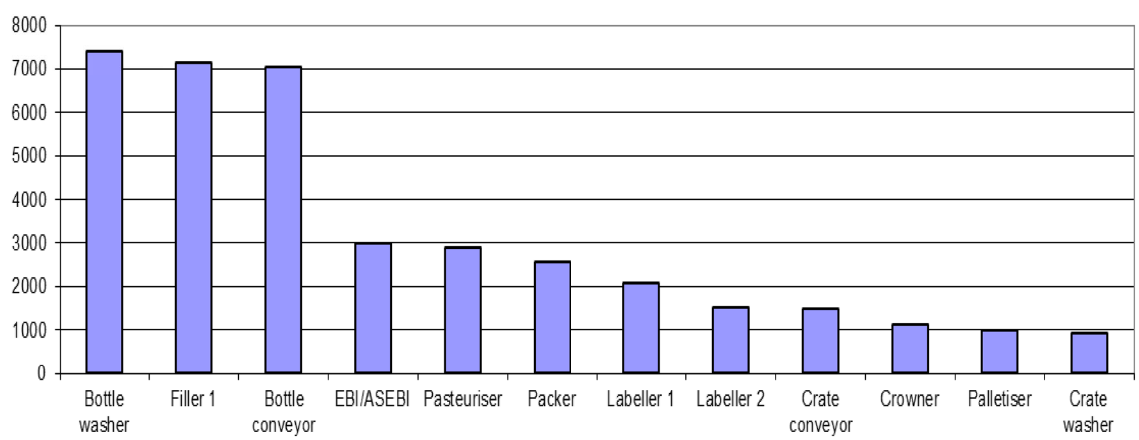


**Figure 2: Summary for packaging line engineering stops**

Figure 3 shows a summary of bottle conveyor stops for the packaging line. The highest number of stoppages due to fallen bottles were experienced at filler followed by Empty Bottle Inspection (EBI). The EBI system is an inline empty bottle inspection system that is capable of inspecting up to 80000 glass bottles per hour. The inspection checks include bottle mouth inspection, outer sidewall inspections, inner sidewall inspection, bottle base inspection, high-frequency residual liquid inspection, infrared residual liquid inspection, and thread inspection.

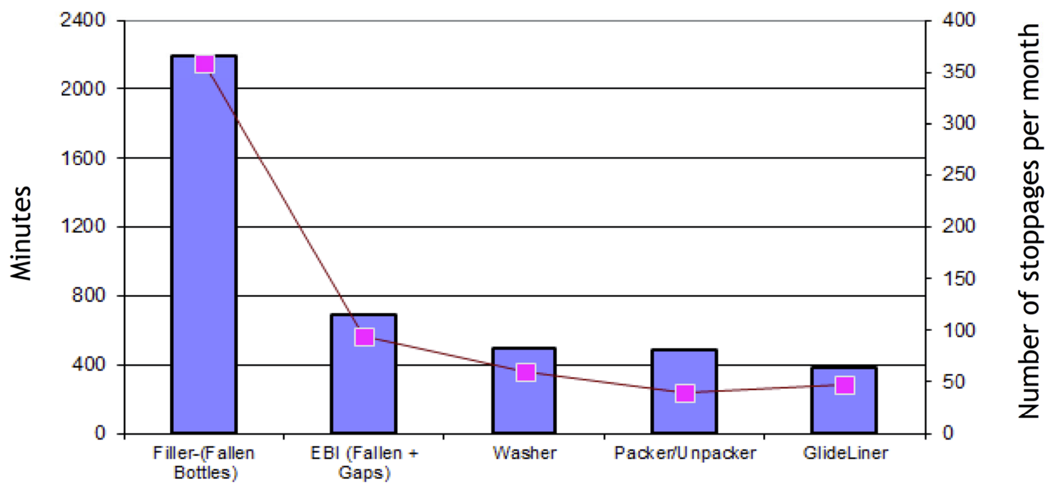


**Figure 3: Summary for packaging line engineering stops**

Therefore, in line with proper problem definition, the problem was found to be filler fallen-bottle stoppages that were resulting in beer loss.

### 4.2 Potential causes for filler fallen-bottle stoppages

An Ishikawa or cause-and-effect diagram was used as a continuous improvement tool to identify and display possible causes for filler fallen-bottle stoppages. The causal factors were established from brainstorming sessions and information obtained from the maintenance department. More causes of filler fallen bottle stoppages were noted from man-machine challenges. It was revealed that some of the operators were failing to follow the right operating procedures hence resulting in more filler fallen-bottle stoppages. The operator mistakes include incorrect wear strip fitting; incorrect filler/crowner timing; incorrect neck guide alignment, and incorrect setup guides. The machine causes for crowner fallen bottles stoppages included loose guides; worn guides; burrs on wear strip, worn bottle pads; incorrect transfer dead plates, worn piston springs; broken piston rod; worn compensation springs; and worn crowner star wheel. Other material causes for crowner fallen bottle stoppages would include bottle and crown defects.

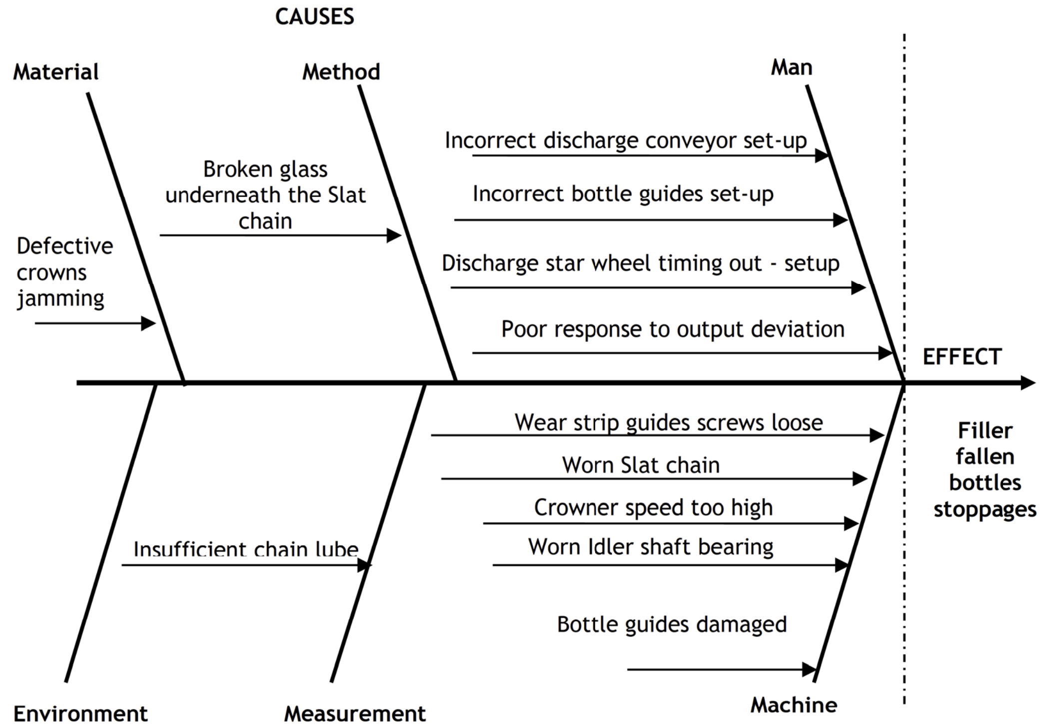


**Figure 4: Ishikawa diagram for filler/crowner fallen bottles stoppages**

The next step was to check if the standards were taken into consideration for each of the causes. Table 1 shows a summary of troubleshooting the potential root causes, the inspection procedures to be followed, and the observations that were made. Concerning incorrectly EBI discharge conveyor set-up and incorrect bottle guides set-up, the essence of periodic job observations (PJO) enhance quality and promote continuous improvement. The team leader and supervisor use an operator instruction sheet (OIS) to observe employees as they are executing their duties doing a job. The OIS is a customised job description for each of the jobs that are executed on the shop floor.

**Table 1: Troubleshooting potential causes for high filler fallen bottles stoppages**

| Potential root cause | Inspection | Observation |
|---|---|---|
| Incorrectly EBI discharge conveyor set-up | Perform PJO to check EBI discharge conveyor set-up | No issues were observed |
| Incorrect bottle guides set-up | Perform PJO to check EBI discharge conveyor set-up | No issues were observed |
| Discharge star-wheel timing out - setup | Perform PJO to check discharge timing after Pack change | No issues |
| Broken glass underneath the Slat chain | Check if there is broken glass underneath slat chains after maintenance day | No issues |

| Potential root cause | Inspection | Observation |
|---|---|---|
| Insufficient chain lube | Check if there is enough chain lube on the infeed and discharge conveyor | No issues |
| Worn Slat chain | Check for worn slat chain | Infeed and discharge slate chains were worn |
| Worn Wear strip guides | Check for worn wear strip guides | Some wear strip guides we worn |
| Wear strip guides screws | Check if the wear strip guides screws are | No issues |
| Worn Idler shaft bearing | Check for worn idler shaft bearings | Discharge idler shaft bearings were worn |
| Bottle guides damaged | Check for damaged bottle guides | No issues |
| Worn returning rollers | Check for worn return rollers | No issues |
| Worn Idler sprocket | Check for worn idler shaft sprocket | No issues |

### 4.3 Implementation of possible solutions

These solutions included creating a schedule to replace slat chains, idler shaft bearings, and wear strip guides. It was also imperative to check if the bottles are still falling due to the worn slat chain and act on any deviation from the plan. Table 2 shows the PDCA steps which were followed for the implementation of possible solutions.

**Table 2: Steps for the PDCA cycle**

| Step | Description | Responsibility | Status |
|---|---|---|---|
| **Plan** | • Create a schedule to replace the slat chain<br>• Create a schedule to replace Idler shaft bearings<br>• Create a schedule to replace wear strip guides | Industrial Engineer | Completed |
| **Do** | • Replace slat chain<br>• Replace idler shaft bearings<br>• Replace wear strip guides | Industrial Engineer | Completed |
| **Check** | • Check if the bottles are still falling due to worn slat chain | Industrial Engineer | Completed |
| **Act** | • Act on any deviation from the plan | Industrial Engineer | Completed |

In order to close the PDCA loop, it was critical to do the following tasks:

- Create a continuous schedule to check slat chain condition or review the frequency;
- Create a continuous schedule to check idler shaft bearings condition or review the frequency;
- Create a continuous schedule to check wear strip guides condition or review the frequency.

## 5 RESULTS AND DISCUSSION

The implementation of possible solutions led to the improvement of the packaging line in terms of reduction of filler fallen bottle stoppages. These include corrective maintenance procedures such as replacing the slat chain, replacing idler shaft bearings and replacing wear strip guides. Figure 5 shows a comparison of before and after scenarios for filler fallen bottle stoppages. The results demonstrate that there is a noteworthy improvement after the interventions on issues that were highlighted by the Ishikawa diagram for filler/crowner fallen bottle stoppages.

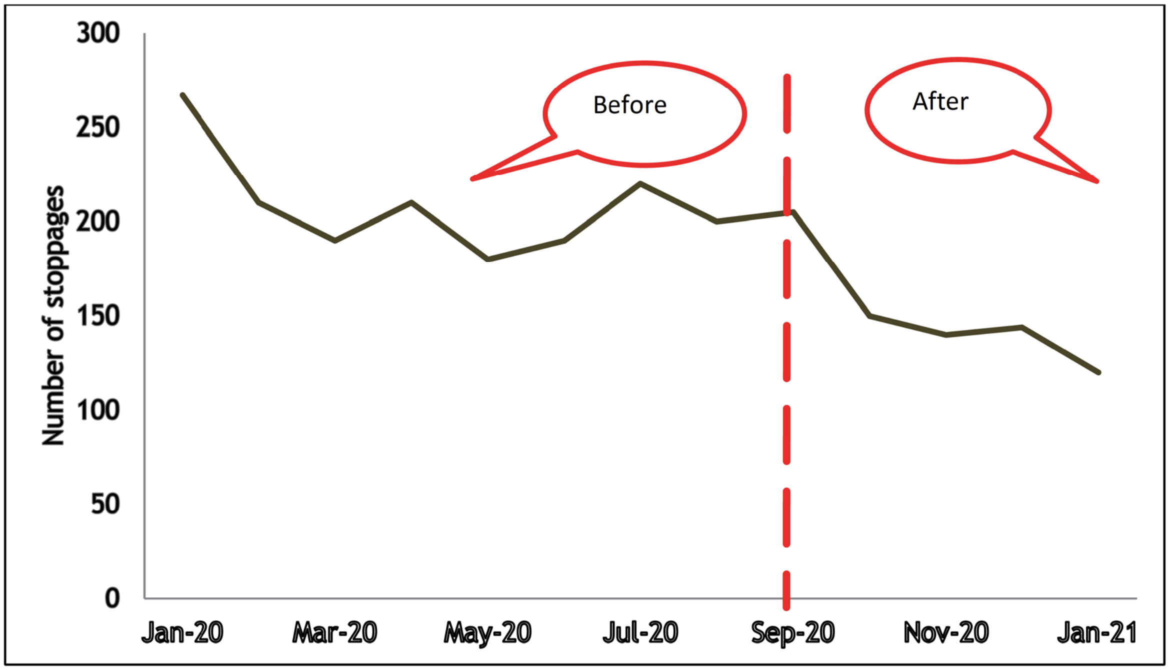


**Figure 5: Comparison of before and after scenarios for filler fallen bottle stoppages**

The results were also validated to establish whether the process changes were responsible for the decrease in the number of filler stoppages or whether it was all due to chance. T-Test can be used to execute a two-sample data sets from two independent populations with unequal variances and can be either one-tailed or two-tailed depending on whether one population mean is greater than the other or if the two population means are different [14]. After initially stating the null hypothesis as population means for the two samples as equal, an independent samples T-test was then deployed to validate the results. The level of significance was set at $p = 0.05$ to reject the null hypothesis, hence if the p-value is found to be $\leq 0.05$, that means the two means of the before and after scenarios are significantly different. Conversely, if the p-value is $> 0.05$ then the null hypothesis is not rejected. Table 3 shows the t-test results of the two samples assuming unequal variances.

**Table 3: t-test results for two samples assuming unequal variances**

| | **Before** | **After** |
|---|---|---|
| Mean | 208 | 125.5 |
| Variance | 642.25 | 312 |
| Observations | 9 | 8 |
| Hypothesized Mean Difference | 0 | |
| df | 14 | |
| | **Before** | **After** |

| | | |
|---|---|---|
| t Stat | 7.853187 | |
| P(T<=t) one-tail | 8.49E-07 | |
| t Critical one-tail | 1.76131 | |
| P(T<=t) two-tail | 1.7E-06 | |
| t Critical two-tail | 2.144787 | |

Statistical tracking was used to validate the results and given that P (T <=t) for the two-tail test is less than 0.05, the null hypothesis is therefore rejected and one can conclude that there has been a noteworthy difference between the before-scenario and the after-scenario.

## 6 CONCLUSION

The study focused on the improvement of a beer packaging line through the deployment of Pareto analysis, root cause analysis, and the use of statistical tracking to validate the results. It was noted that waste during beer production is a challenge given the escalation of production costs and compromisation of the efficient use of resources. Lean manufacturing tools can be used to identify bottlenecks and determine losses in line efficiency, and thereafter provide solutions to optimise packaging operations for a beer production line. It was also noted that the PDCA is an iterative technique for continuous improvement and can be exploited to improve the beer packaging process efficiency. The root causes of beer loss during the packaging process as a result of filler fallen-bottle stoppages were identified and cost-effective measures on the packaging line were instituted to reduce the loss. Statistical tracking can be used to validate the results of a continous process improvement in production systems. A further research study may embrace recent developments in big data and analytics to foster continuous improvement initiatives in packaging processes for breweries.

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