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Improvement of Output and Waste Reduction Through Equipment Reverse Deterioration in an FMCG Industry: A TPM 4-Phases to Zero Breakdowns Approach

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Abstract

Fast moving consumer goods (FMCG) industries are some of the industries that are characterized by manufacturing of vast variety of products whose profitability bears sustenance in output volumes. The need to maintain high output and outcompete competitors in the global market lies with apprenticing various equipment efficiency enhancement strategies. One of the impediments to the attainment of high efficiencies in these industries is the amount of waste loss incurred during manufacturing, predominantly resulting from equipment failures. A fast-moving consumer goods industry in the line of match sticks manufacturing was plagued with exorbitant waste losses generated by equipment failures which impacted adversely on the goal of increasing their manufacturing output. The paramountcy of the problem acuminated directly to the absence of an equipment reverse deterioration approach in their maintenance operating system. This was emulated by significant evasions of material during processing which resulted in material contamination and presented major write-off losses and reduced output. The magnitude of the problem in this organization goaded the study to derive an aim of adopting the total productive maintenance (TPM) 4-phases to zero breakdowns to circumvent waste generation from equipment failures and maximize manufacturing output. The results of the study were a simplified equipment reverse deterioration approach that saw a significant reduction in waste and an improved output glide path for the organization.

Keywords
Output, Waste, Equipment failures, Reverse deterioration and Efficiency.

1. Introduction
Fast moving consumer goods (FMCG) industries are at the realm of driving global economic competitiveness through the vast variety of products they usher into the markets. With this vast variety, there is a strong need for these industries to ensure optimal attainment of output and eliminate waste in their manufacturing operations. The elimination of waste generated from the manufacturing processes talks directly to the employment of waste reduction techniques and methodologies from various platforms of study. According to Nwabekee et al. (2024) waste reduction in FMCG industries is one of the major cost drivers and a significant approach towards the enhancement of product output. At

the heart of subduing the ever-growing challenge of waste reduction, is the need to ensure optimal performance of manufacturing equipment to ensure the protection of product quality during processing. This brings into play the significance of equipment reverse deterioration as one of the major principles of driving waste reduction. Aleksic et al. (2022) made emphasis that the equipment failure, breakdown, and malfunction are the major sources of contamination and waste generation in consumer goods industries. The problem is further exacerbated by an almost impossible task of reworking or reusing wasted products. This puts a lot of pressure on these industries as equipment failure results in an instant write-off of large quantities of raw material. This is also cemented by the nature of the equipment that is being used to process raw materials which range from heating, stirring, chemical mixing, temperature setting, conditioning, conveyance and sorting operations that must always be kept in a closed loop. Any escapes from the product during these operations present foreign contamination and non-conformance to the required quality standards of the products. This makes it imperative for the industries to drive equipment reverse deterioration to circumvent themselves to the detriment of such in-process losses. Nurprihatin et al. (2019) advises that equipment reverse deterioration programs such as reliability centered maintenance (RCM), total productive maintenance (TPM), and predictive maintenance (PdM) have been recognized consistently as key strategies to eliminate waste and equipment downtime. Within the context of TPM and RCM, equipment reverse deterioration can be define as the process determining and executing preventive maintenance efforts to restore equipment back to basic operational conditions. Embodied in the total productive maintenance strategy, are the four phases to zero equipment breakdowns that are core to the approach of this study to drive equipment restoration and waste reduction in an effort to enhance output. There is a need for FMCG industries to embark on equipment reverse deterioration strategies to extricate themselves from significant economic losses of waste to enhance competitiveness on a global scale.

1.1 Objectives

- To articulate the loss impact of waste generated by the failure of equipment on the organization's strategic goal of attaining higher product output.
- To analyze the impact of output losses in the form of waste through a stratification process to identify equipment of concern to be subjected to reverse deterioration.
- To carry out a deep dive root-cause analysis to on the equipment that is contributing significantly to major waste generation and derive reverse deterioration solutions thereof.
- To utilize the total productive maintenance 4-phased approach to zero equipment breakdowns as the base method approach to drive equipment reverse deterioration.

2. Literature Review

Equipment reverse deterioration is one of the key drivers of restoration or refurbishment of equipment back to basic operational conditions (Mehmeti et al. 2018). This is a process that is driven by various manufacturing strategies, predominantly through preventive maintenance and predictive maintenance. Preventive and predictive maintenance approaches in this regard play a significant role in periodically checking operational conformance and performance of machines, whilst also ensuring equipment service interval requirements are adhered to. The need for equipment reverse deterioration may be warranted by several factors which include, but are not limited to aged equipment, poor adherence to service intervals (Tsarouhas 2020), total malfunction of equipment, poor quality output and waste generation (Mhlanga et al. 2023), and overall equipment neglect (Sachs 2019). Amrina et al. (2019) advises that these factors not only affect organizations from a downtime incurrence perspective, but also from a material loss perspective. FMCG companies are not immune to this impact and suffer most from material losses due to equipment failures. Equipment failures in these industries pose significant penalties in that failed equipment interrupts processing operations that rely on continuous flows to ensure product quality conformance (King 2019). An example of this phenomenon in the FMCG industry can be the process of tempering chocolate mixture in a tempering unit. Any malfunction of the tempering process results in temperatures dropping significantly or rising significantly, resulting in the tempered material mix being out of specification. The resort to recover from the failures warrants the need to drain material and declare the material as waste. According to Nainaar and Masson (2018) the inability of organizations to manage equipment performances through adherence to their periodic needs has seen many organizations relinquish their competitive advantages and suffer major operational efficiency losses and costs.

The need for FMCG industries to manage waste generation is unraveling at a fast pace that is fueled by an ever-growing competitive market. This has made it imperative for these organizations to embark on various recovery strategies to minimize impact on their production targets. One such strategy to subdue the impact of waste losses is recommended by Cudney (2016) as that of utilizing the 4-phases to equipment zero breakdowns. This principle is defined by Azid et al. 2019 as the use of a four-staged approach of eliminating forced deterioration, corrective maintenance, monitoring and control of deterioration, and the establishment of predictive maintenance efforts to ensure sustainability. Gotoh (2020) expands on the elimination of forced deterioration as the identification of elements that contribute to the early wear and tear of equipment. This process stems from equipment maintenance neglect which has resulted in the accumulation of abnormalities on equipment. Corrective maintenance is outlined by Moussana (2021) as the process of restoring identified abnormalities on equipment and bringing back equipment closer to their original operational standards. The process of corrective maintenance is crucial towards recovery from potential failures and those that have already occurred. Corrective maintenance efforts pose a strong need for monitoring and establishing control. This third phase of zero equipment breakdowns is concerned with the establishment of monitoring mechanisms to ensure that the upkeep of deterioration that has been reversed is upheld. Such upkeep in many manufacturing organizations is attained through the employment of periodic inspections, time-based maintenance, and condition-based monitoring (Gackowiec 2019). These monitoring mechanisms are imperative towards the establishment of predictive maintenance, as they form the historical base to which equipment behavior data can be extracted from. Predictive maintenance in this regard talks to the introduction of equipment monitoring instruments to enhance early detection of equipment abnormalities by means of issuing warnings and failure faults. In the FMCG sphere, these instruments are crucial to the adherence to measurement standards such as temperature, pressure, tank levels, and material feeding into equipment. These are predominant elements that govern manufacturing processes in FMCG industries.

Equipment reverse deterioration is not only significant towards the elimination of waste but is a key aspect of measuring an organization's overall equipment efficiency. The overall equipment efficiency is driven by three core elements which are production output, good quality products produced, and machine availability during the production of the goods (Hermans and Tamás 2024). Literature indicates that various FMCG industries have harnessed the benefits of driving a total productive maintenance culture in their manufacturing streams. This is a culture that is centered around inclusiveness in the process of overcoming equipment failures, waste reduction and the elimination of sporadic and chronic stoppages. The employment of such a program has seen South African FMCG companies such as Unilever, Nestle and Coca-cola attaining significant increases in their overall equipment efficiencies (Uzoigwe 2024). Such achievements stem from driving maintenance activities and giving ownership and decision making to operators on the maintenance of their equipment. Further to this, a critical element to this drive emanates from the process of identifying sources of contamination or sources of waste to ensure that waste produced is as minimal as possible (Labiyi 2019). Cementing the understanding that manufacturing is not only about pushing numbers to reach production targets but ensuring that all products produced are of high-quality standards is the basis to which a successful TPM program is driven. Waste in manufacturing streams is an overall dependent element on the three elements of overall equipment efficiency. The occurrence of downtime in a process directly affects the quality of the product that is produced, and the failure of equipment directly affects the quality of the products that are produced. A manufacturing stream can attain 100% equipment availability and 100% output, while quality of products is of inferior standards. On the contrary it is nearly impossible in the FMCG industry to produce 100% quality products while machine availability and production output are of an inferior standard. Singh et al. (2018) advises manufacturing organizations in this regard to invest in the mindset of maintaining equipment for quality.

There is vast literature available on the principles of equipment maintenance as guidelines towards enhancement of operational efficiencies. However, there is little integration of the principles towards a structured approach to reduce or eliminate waste through equipment reverse deterioration. Various contributions from various authors indicate a gap in the dedication of streamlined techniques that aim to drive the mindset of quality maintenance. Contributions in the field of total productive maintenance have indicated the significance of establishing maintenance operating systems and the benefits thereof that could be harnessed by FMCG industries. The plight of these industries to maximize their production output whilst maintaining operational stability through waste elimination prompts the need to explore various techniques and methodologies to circumvent this problem. The competitiveness of these organizations is dependent on the attainment of good overall equipment efficiencies which are deemed to be above 90% from a total productive maintenance perspective (Rosli 2020).

3. Methods

The enhancement of output and effecting a reduction in waste generation in this organization required a strategic approach that streamlined a sequence of steps to be followed. The study undertook the exploration of the total productive maintenance 4-phases to zero breakdowns philosophy to attain anticipated results. Each of the phases was defined accordingly and the elements that were necessary to aid the study in each phase were outlined. The first phase of the study was to embark on a stratification process that would lead to the elimination of forced deterioration through a focused approach. The second phase was concerned with the physical execution of equipment reverse deterioration through corrective maintenance to the highest contributing equipment to waste generation and output losses. This was followed by the third phase of thoroughly examining reverse deterioration efforts and monitoring equipment to sustain the effort of maintenance work that was carried out. The last phase of the methodology focused on the establishment of predictive efforts to drive the upkeep of machinery. Due to investment constraints, the study only drew recommendations to the organization on where predictive maintenance instrument could be implemented. The detailed outline of the inputs and outputs of each of the steps was as follows:

3.1 Elimination of forced deterioration

In its definition, this phase of the study is concerned with the establishment of focus and the assessment of the current state of the problem. This phase commenced with gathering production output data and waste generation data for a period of six months and analyzing the data. The data was then translated into a graphical representation of the historical performance of the organization. This entailed an outline of the output that was historically targeted month by month and the actual output that was achieved. Further to this, a graphical outline of the waste generated through manufacturing streams and its impact on the output was generated. To set the pace for the study, in alignment with the organization's output objective, a consolidated glide path was drawn, which depicted historical targets and actual attainment for both output and waste generated. Future targets for output and waste reduction were also outlined respectively, signaling the organization's future vision of productivity. This process was then proceeded by a Pareto graphical outline of the type of defects that yielded to waste, with the focus being on the highest waste defect generated. The waste from the highest defect was then linked to each processing equipment and the amount of waste generated from each equipment relative to the highest waste defect. The equipment with the highest waste generation was concluded to be subjected to equipment reverse deterioration activities.

3.2 Carry out corrective maintenance

This second phase of the study was characterized by physically executing equipment reverse deterioration on the equipment, thereby reversing all abnormalities identified and returning the equipment back to operational conditions. To carry out this activity through a structured approach, the equipment of concern that generated the highest waste was subjected to a root-cause analysis process. The root-cause analysis process was in the form of an Ishikawa diagram, where possible failures that could have led to the generation of waste were articulated. Through a verification process, the actual root-causes were identified. The thorough root-causes from the Ishikawa diagram technique formed the base corrective maintenance actions that were needed to reduce waste generation from the equipment. This step was then followed by a thorough draft of a project plan detailing out the time frame and the actions that were to be taken to restore the equipment back to basic operating conditions. The project plan was then handed over to the technical team, and reverse deterioration requirements were then executed. The reverse deterioration efforts in this phase were depicted on an action plan list, indicating the before and after pictures of the performance of the equipment.

3.3 Monitoring and control

The monitoring and control phase was critical to the validation of the equipment reverse deterioration work that was performed. This phase took the study towards performance monitoring post restoration of equipment. The validation process in this regard was crucial towards the elimination of assumptions that all components that were restored were functioning optimally. This phase included carrying out minor adjustments, strength and stress tests and overall performance inspections. To facilitate this phase of the methodology, a periodic inspection procedure was drafted to ensure that abnormalities were curbed as early as possible. Further to this, there was a focus on the areas where waste was being generated, and the periodic inspection provided the much-needed assurance that the equipment was performing their intended function and there was a closed loop for waste generation. The inspection in this regard was outlined in the form of a preventive maintenance workorder. The structure of the preventive maintenance workorder was equipped with a criticality criterion for each of the items that were being inspected. The monitoring and control phase went on to check the results of the performance of the equipment against waste generation and output which were presented graphically on the results topic.

3.4 Carry out predictive maintenance

The predictive maintenance phase of the study was concerned with the establishment of monitoring mechanisms that were able to give off warnings of failures and largely provide fail-safe conditions. The study identified key areas of investment on predictive instruments to monitor substandard performance of equipment that could later lead to deterioration. Due to time frame and investment constraints on predictive maintenance tools and resources, the organization opted to stabilize and sustain the first three phases of the methodology and focus on predictive maintenance as a future stand-alone project. Recommendations on predictive maintenance included vision cameras with ability to stop the belt when protection flaps fail, load cells that triggers an alarm when catchment on the hopper is full, and Sick floor sensors which are shape programmable at spillage areas to detect minor to major spillage heaps to give off an early abnormality detection alarms to prevent losses.

4. Data Collection

4.1 Production output and waste generation data

The first phase of data collection focused on gathering data for a period of six months, looking at targeted and actual outputs. Table 1 is a collective depiction of the data collected. The data that extends five months after the actual values in August 2024 indicate the targeted production output and the daily ramp up that the organization was to embark on. As part of the future goals of the organization, the targeted daily production output was to increase on four monthly terms. The data further indicated that the monthly targets for the plant were determined by the number of days in a month as opposed to a standard value each month. The company targeted a waste value of 3% across all months and the data indicated an extensive exceed of the target based on actual waste generated.

Table 1. Production output and waste generation data

Measurement	Output and waste generation (Tons)										
	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25
Daily output target	24	24	24	24	26	26	26	26	28	28	28
Operational days	19	22	22	19	23	21	19	23	21	14	23
Month output Target	456	528	528	456	598	546	494	598	588	392	644
Actual average daily output	17,5	18,3	21,6	20,5	21,4	16,4					
Month actual output	332,5	402,6	475,2	389,5	492,2	344,4					
Target waste loss (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Daily average waste loss	2,3	3,1	3,2	2,1	2,6	2,3					
Acutal Waste loss (%)	13,1%	16,9%	14,8%	10,2%	12,1%	14,0%					
Month Output less Waste	288,8	334,4	404,8	349,6	432,4	296,1					
Month actual waste loss	43,7	68,2	70,4	39,9	59,8	48,3					

4.2 Waste defect stratification data

Stemming from the waste generated across the six-month period, the study collected data on the types of waste that were being generated to accumulate to the sum of each month. Eight defects that generated the collective waste were identified and each of their monthly contributions to the course were tallied. Over the period of 6 months, a total of 330,3 tons of waste was generated, and at a glance, the highest contributing waste defect was spillage contamination, hitting highs of 240,9 tons which contributed to 73% of the waste that was generated cumulatively. Table 2 depicts the collective summary of the waste quantities that were generated by the plant. Brief investigation into the spillage defect indicated several equipment failures that resulted in splints or sticks spilling out of process during production. The spillages were stepped on or driven over by forklifts and other moving machinery due to the nature of operations and ultimately resulted in waste.

Table 2. Waste generation by defect summary

Defect description	Waste generated by defect (Tons)						Total tonnage loss	Average month loss	Average Month % loss
	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24			
Thin sticks	1	0,6	4,3	1,6	2,1	1,8	11,4	1,9	3%
Thick sticks	2	1,3	3,8	2,3	2,4	2,3	14,1	2,4	4%
Spillage contamination	36,4	47,9	54	29,8	40,1	32,7	240,9	40,2	73%
Poor length cut	0,4	2,1	2,3	2,1	4,1	4,9	15,9	2,7	5%
Centre broken	0,3	1,9	2,7	1,7	2,3	3,1	12	2,0	4%
Poor chemical mix	0,9	6,4	3,3	1,3	3,8	2,7	18,4	3,1	6%
Wet sticks	2,1	2,7	0	0,7	3,1	0,7	9,3	1,6	3%
Over-dry	0,6	5,3	0	0,4	1,9	0,1	8,3	1,4	3%
Total Month Waste	**43,7**	**68,2**	**70,4**	**39,9**	**59,8**	**48,3**	**330,3**		**100%**

4.3 Highest defect waste generation by equipment data

The study took interest in the spillage contamination waste defect from the waste generation data. The study explored the large quantities that were measured from multiple equipment across the manufacturing plant. Table 3 indicates the waste generated by equipment in respective areas of spillage. Data was collected from end shift reports on the amount of waste that was collected within the vicinity of the equipment. This data was key towards understanding the contributions of each equipment to the waste loss incurred.

Table 3. Spillage contamination waste by equipment summary

Equipment description	Spillage contamination waste generation by equipment (Tons)						Total tonnage loss	waste % ratio
	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24		
Log Peel	0	0	0	0	0	0	0	0%
Guillotine cutter	1,9	1,3	0,2	1,1	0,4	2,3	7,2	3%
Transfer belts	3,1	4,6	2,9	1,8	2,4	1,9	16,7	7%
Cross conveyors	12,6	17,2	23,1	11,9	16,2	13,2	94,2	39%
Stirrer	0	0,4	0,1	0,2	0	0	0,7	0%
Heater booth	0,7	2,1	2,2	1,3	1,1	3,1	10,5	4%
Tumbling drums	2,1	1,6	1,6	1,8	2,4	2,8	12,3	5%
Accumulation Hopper	11,3	18,4	21,6	9,8	14,3	8,9	84,3	35%
Peroxide tanks	3	1	0,2	1,4	0,6	0,1	6,3	3%
High speed belts	1,7	1,3	2,1	0,5	2,7	0,4	8,7	4%
Total	**36,4**	**47,9**	**54**	**29,8**	**40,1**	**32,7**	**240,9**	**100%**

5. Results and Discussion

5.1 Elimination of forced deterioration results

The forced deterioration elimination phase commenced with a graphical depiction of the month-to-month targets, actual production output and waste generated. The results depicted by Figure 1 in this case indicate that over the six months of data collection, the organization targeted a production output of 3112 tons of match sticks and only achieved a total production of 2436,4 tons, which constituted a 78,3% schedule adherence. The schedule adherence was further depleted by the amount of waste that was generated during production. A total of 330,3 tons of production was lost into waste, bringing the profitable production output to 2106,1 resulting in a profitable schedule adherence of 67,7%.

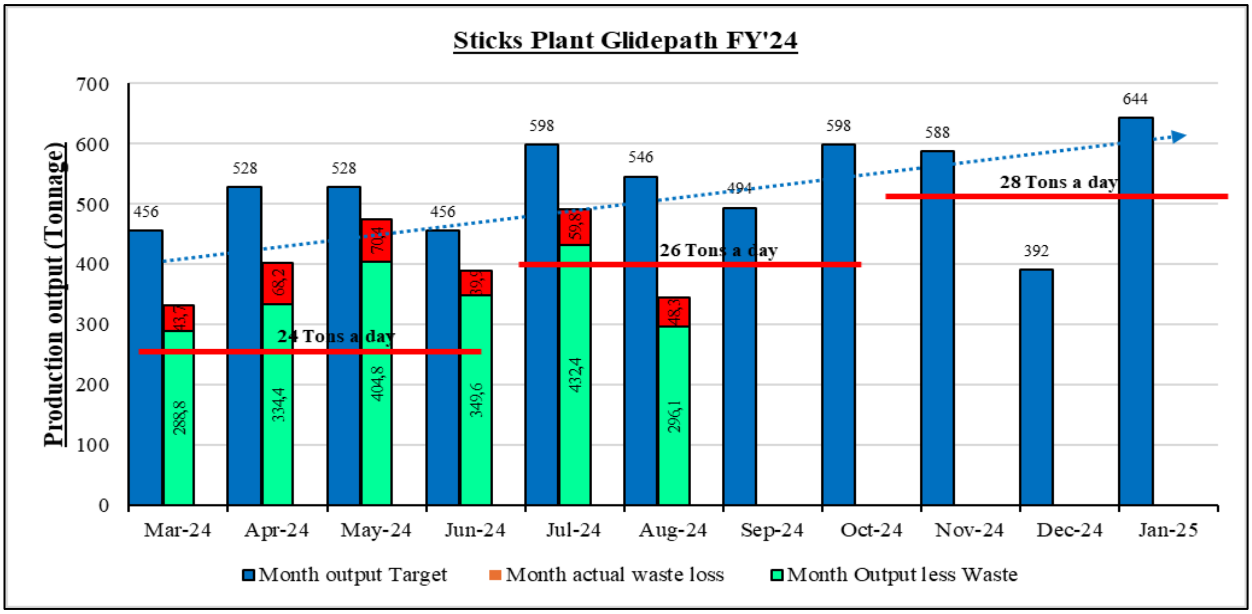


Figure 1. Production output glidepath

The waste data depicted on the glidepath led to a stratification process utilizing the Pareto analysis technique. The Pareto analysis results acuminated to the spillage contamination as the main waste contributor, of which according to the 80/20 rule, was the only defect that fell within the 20% vital few tangent. The stratification went further to identify the equipment that was contributing significantly to the spillage contamination. A secondary Pareto analysis was then carried out, and the results of the analysis indicated two pieces of equipment, which were cross conveyors and accumulation hopper to be equipment of concern. The equipment fell within the 20% vital few tangent and had a combined contribution of 178,5 tons, which was more than 50% of the total waste generated over the six month period. Figure 2 indicates the Pareto analysis results that were undertaken to narrow down the equipment that needs to be subjected to equipment reverse deterioration.

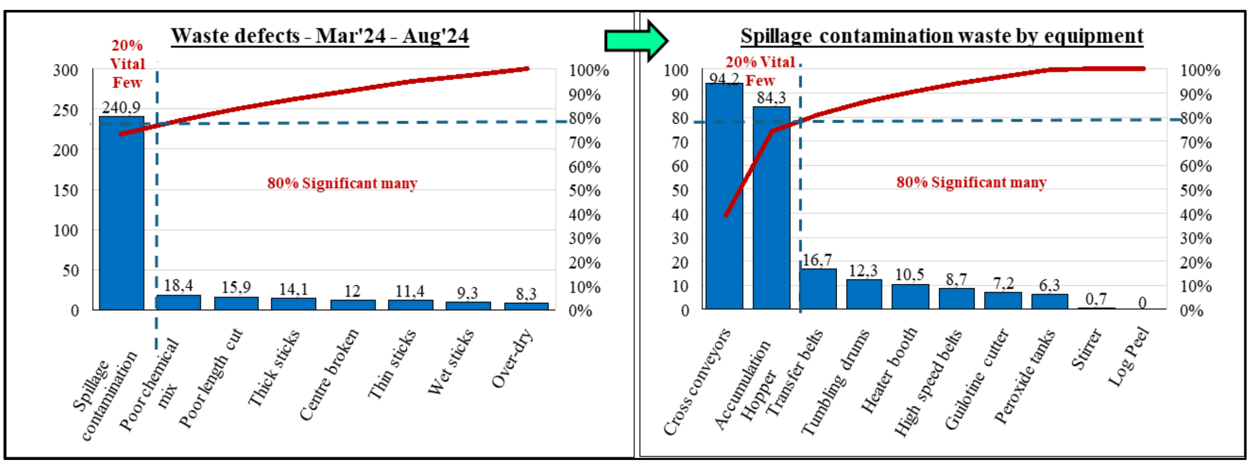


Figure 2. Waste and equipment stratification

The results of the Pareto analysis stratification prompted a deep dive root-cause analysis on the possible causes of the spillage contamination waste from the equipment. Figure 3 indicates the results of the root-cause analysis approach through an Ishikawa diagram. The exploration of the possible causes from the 5Ms+1E indicated five machine root-causes upon verification. These were the deteriorations that needed to be eliminated from the equipment to effect waste reduction by more than 50%.

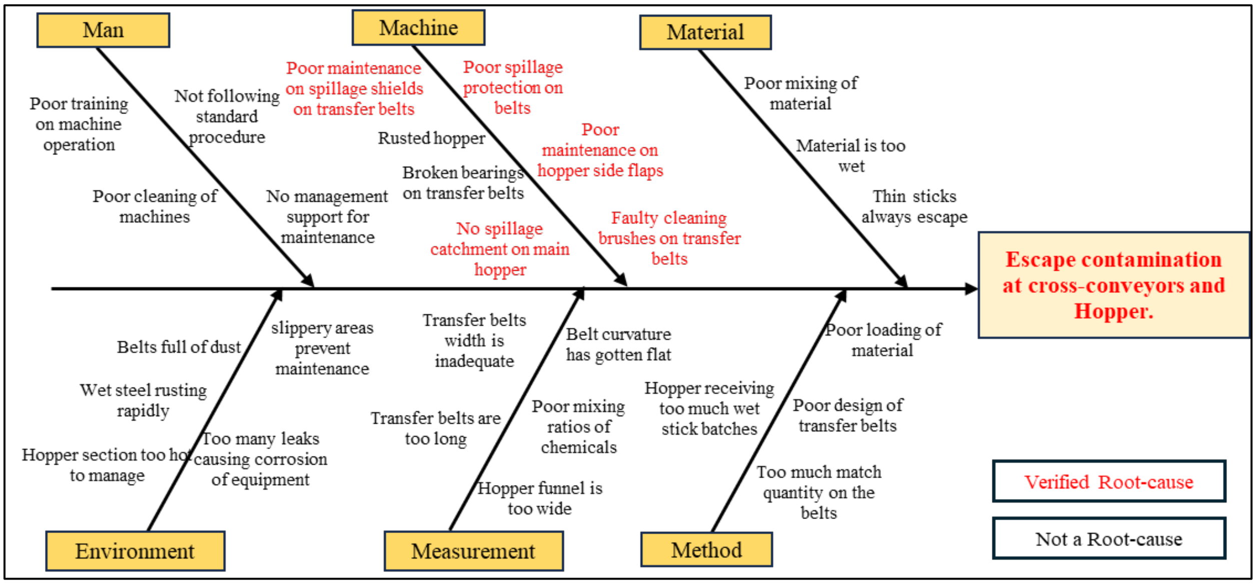


Figure 3. Equipment failure root-cause analysis

5.2 Carry out corrective maintenance results

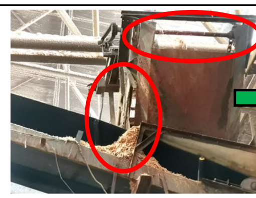
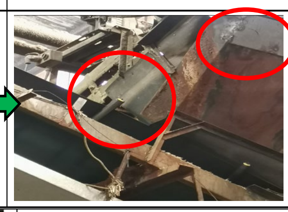
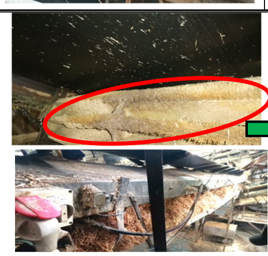
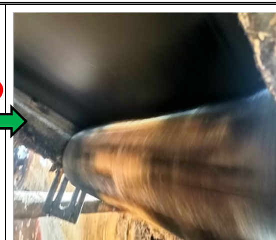
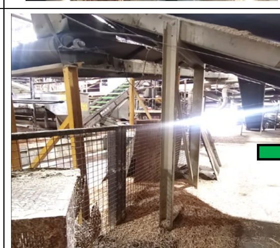
The second phase of the study was to carry out corrective maintenance. The results of the Ishikawa diagram on Figure 3 beaconed the direction of the equipment weaknesses that needed restoration. The root-causes were treated as restoration milestones, with detailed actions that were undertaken to restore the equipment back to basic conditions and eliminate product spillages. Table 4 indicates the project plan that was compiled and the nature of activities that were carried out to eliminate deterioration of the equipment.

Table 4. Corrective Maintenance action plan

Sticks Plant Equipment Reverse Deterioration Plan - Aug'24 - Sep'24					
Activity	Time Frame				
	Aug -week 4	Sep - week 1	Sep - week 2	Sep - week 3	Sep - week 4
Poor spillage protection on belts					
Clean spillage barrier and remove mountings					
Reinforce structural integrity of barrier					
Renew spillage catchment scrapper					
Install restored spillage barrier					
Poor maintenance on hopper side flaps					
Strip out current flaps					
Cut out new flaps from galvanized sheet					
Drill and mount protective flaps					
Faulty cleaning brushes on transfer belts					
Strip out current brushes					
Deep clean brush area					
Change or clean brush combs					
Poor maintenance on spillage shields on transfer belts					
Fabricate new spillage shields					
Remove old shield and install new shield					
No spillage escape catchment on main hopper					
Design new gutter catchment					
Install gutter catchment					
Install recycle bin on new hopper gutter					

The results of the corrective maintenance project plan are depicted by Table 5, which indicates the before and after conditions of the equipment post reverse deterioration phase. All equipment deterioration in all areas of spillages on the stratified equipment were addressed.

Table 5. Corrective Maintenance before and after depiction

No#	Area/Maintenance item	Problem Description - Brief	Picture Before	Picture After	Comment
1	**Poor spillage protection on belts**	The splint spillage barrier is not adequately preventing splints from over flowing - **Source of waste** when Forklift and Bob-cat drive on spillage. Spillages get stepped on by forklifts and Bob-cat.			
2	**Poor maintenance on hopper side flaps**	The side flap that is supposed to prevent side spillage is not functioning or attached to the conveyor. **Source of waste.** The catch tray is not long enough and causes a spillage to the small peroxide pump. **Source of waste.**			Work was partially done. The blanket flap is still not attached to the catch tray. Still causing a spillage.
3	**Faulty cleaning brushes on transfer belts**	The brush is rotating freely without effecting any of its intended function on the conveyor. 30 - 50mm gap. **Source of waste.** Spillage on driveway as opposed to recycle belt.			Gap has been closed. Brush roller is performing its function. The only challenge is when the roller runs opposite direction. There is no brush for opposite direction.
4	**Poor maintenance on spillage shields on transfer belts**	Splints are spilling out of the conveyor onto the floor.			Install shield underneath the conveyor to block splints from falling 
5	**No spillage escape catchment on main hopper**	Spillages of splints occurring due to directional spillage tray similar to Hopper No.1. Splints fall on the floor, get driven on by forklift and Bobcat the become waste. **Source of Waste.**			Catch tray has been installed.

5.3 Monitor and Control results

The monitoring and control phase was concerned with cementing sustainability of the corrective maintenance actions. Table 6 indicates the preventive maintenance inspection that was undertaken weekly to ensure that deterioration is monitored, and spillages do not occur. The inspection template also fostered collaborative sign-off between maintenance and production to cement validity of equipment condition.

Table 6. Equipment Inspection procedure

Preventive Maintenance Workorder					
Inspection Item			**Condition criteria (Tick)**		
			Good	**At Risk**	**Immediate fix**
Spillage barrier					
Verify that all mounting bolts on the spillage barrier tightened properly					
Check the structure of the barrier for any wear and tear					
Check for any material spillages on the barrier					
Hopper Flaps					
Verify that the hopper side flaps are mounted properly					
Check for any material spillage on the side flaps					
Check hopper enclosures for any weld cracks					
Belt Brush					
Verify that the brush is mounted properly					
Ensure that the brush is rotating freely in the opposite direction of the belt.					
Ensure that the brush is adjuste flush with the belt					
Conveyor shields					
Verify mounting of conveyor spillage protection shields					
Hopper					
Verify that the hopper gutter is mounted properly.					
Ensure that recycle bin is placed on the gutter.					
Check for any floor spillages from the hopper.					
Contractor / Artisan		**Production**		**Maintenance Personnel**	
Name:		**Name:**		**Name:**	
Signature:		**Signature:**		**Signature:**	
Date:		**Date:**		**Date:**	

The monitoring phase also focused on the production output and waste generation results after carrying out corrective maintenance. Table 7 indicates the data that was collected for an extended period from September 2024 to January 2025. The data supported the overall final results of the impact of the equipment reverse deterioration journey.

Table 7. Production output and waste generation results

Measurement	**Output and waste generation (Tons)**										
	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25
Daily output target	24	24	24	24	26	26	26	26	28	28	28
Operational days	19	22	22	19	23	21	19	23	21	14	23
Month output Target	456	528	528	456	598	546	494	598	588	392	644
Actual average daily output	17,5	18,3	21,6	20,5	21,4	16,4	22,1	24,2	26,8	25,9	27,2
Month actual output	332,5	402,6	475,2	389,5	492,2	344,4	419,9	556,6	562,8	362,6	625,6
Target waste loss (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Daily average waste loss	2,3	3,1	3,2	2,1	2,6	2,3	0,9	0,8	1,1	1	0,4
Actual Waste loss (%)	13,1%	16,9%	14,8%	10,2%	12,1%	14,0%	4,1%	3,3%	4,1%	3,9%	1,5%
Month Output less Waste	288,8	334,4	404,8	349,6	432,4	296,1	402,8	538,2	539,7	348,6	616,4
Month actual waste loss	43,7	68,2	70,4	39,9	59,8	48,3	17,1	18,4	23,1	14	9,2

The overall results of the project indicated an improved glide path in terms of the attainment of actual production output and the reduction of waste. Over the breakpoint five months post equipment reverse deterioration, the plant targeted a production output of 2716 tons and attained 2527,5 tons, constituting an improvement from a 78,3% schedule attainment to a 93,05% schedule attainment. With a subtraction in the amount of waste generated, the plant recorded an average profitable output of 90%, claiming an average profitable output improvement of 23%. The results further indicated a significant reduction in the amount of waste that was generated, with an improved record from a monthly average of 13,6% to 3,4%. Although the results did not reach the targeted 3% waste generation target set by the organization, there has been a significant reduction of 10,4% in waste generation. The average monthly loss through waste generation reduced from an average of 55 tons to an average of 16,36 tons, which represented an improvement of more than 50%. Figure 4 summarizes the overall outcomes of the results of the study.

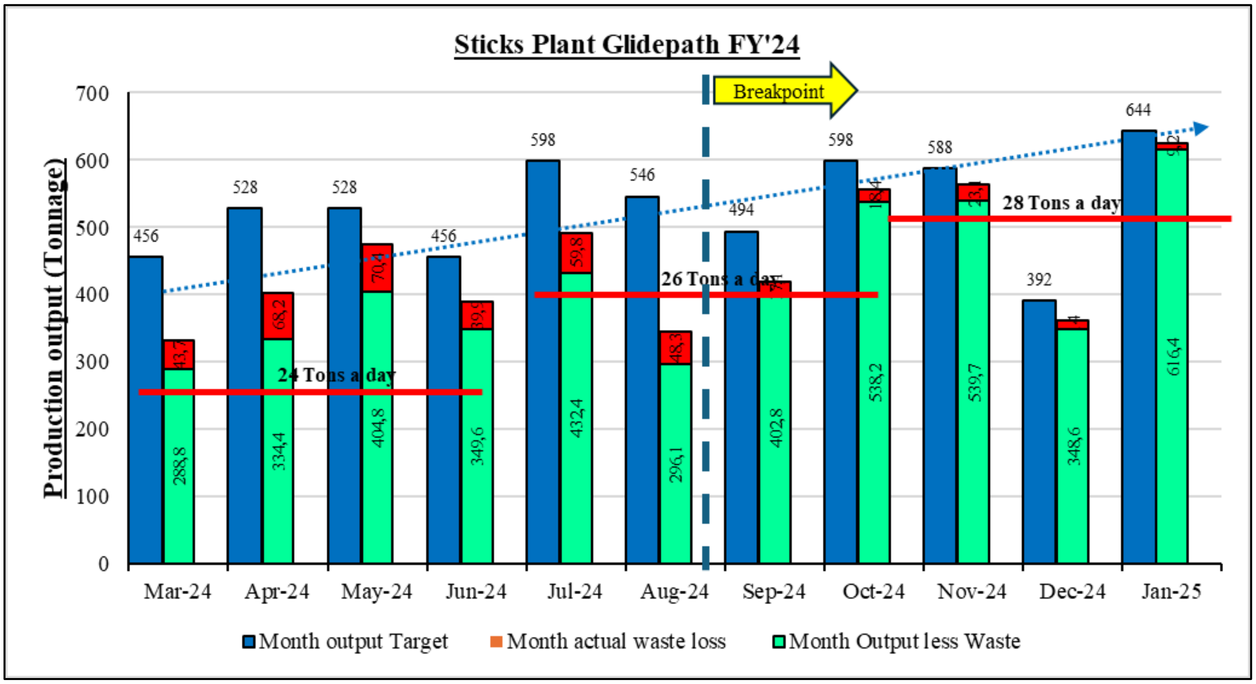


Figure 4. Glide path improvement results

6. Conclusion

The study has largely demonstrated the effectiveness of the 4-phases to zero breakdowns technique. Through a stratification process and robust data collection process, the significance of deriving a focused improvement approach has been cemented. Concerned with outlining the impact of equipment failure relative to waste generation, the first objective of the study was attained through a detailed outline of waste data collected prior to the study and post the study. This was further supported by the impact outline of a significant reduction in waste generation after equipment was restored back to basic conditions. The second objective of the study was attained through a double Pareto analysis stratification, where the highest defects that fell within the 20% vital few were identified. The identification of the highest defect further led to equipment stratification in the form of a Pareto chart, which stratified the equipment that contributed the highest to the stratified defect. The third objective was achieved through an outline of an Ishikawa diagram that derived the root-causes to the main defect. This was then supported by a project plan and an evidence-based equipment reverse deterioration process. The last objective of the study was attained through a methodological outline of the 4-phases to zero breakdowns, which became the guideline towards achieving the overall results of the study. The last phase of the study proved to be a constraint in terms of investment, but the first 3-phases have also proven to be significant towards attaining stability in waste reduction and the attainment of high production output.

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