

IMPROVEMENT OF MATERIAL HANDLING SYSTEM FOR COIL TRANSPORTATION IN THE MANUFACTURE OF ALUMINIUM ROLLED PRODUCTS

M. Dewa^{1*}

¹Department of Industrial Engineering
Durban University of Technology, South Africa
mendond@dut.ac.za

ABSTRACT

The manufacture of aluminium rolled products is characterised by coil transportation, which is a process of moving the metal and lot tickets from one point to another for further processing at other sub-plants. The case study organisation is facing challenges on coil transportation and hence failed to deliver material on time and could not achieve manufacturing targets. The paper aims to identify the factors leading to the failure of achieving targeted schedule and introduce the system to standardize the process. As methodology, a flow diagram was used represent the current process and a failure mode and effect analysis was conducted to document and analyze the failures and implement mitigating factors. Breaking up of batches and delayed material arrivals to processing stations were found to be the key reasons that led to process inefficiency. An improved process flow was proposed and the recommended actions led to a streamlined flow characterised by reduced delayed material arrivals and processing.

* Corresponding Author

1 INTRODUCTION

The aluminium industry in South Africa is a key industrial pillar of the South African economy that has a significant economic impact through contribution to the fiscus, generation of significant foreign exchange revenues and providing decent jobs to about 11 600 employees [1]. The case study organisation is one of the big players in the aluminium industry that produces aluminium products that include rolled products, extrusions and containers. Rolled products are supplied as a range of specialized and standard aluminium rolled products to customers locally and internationally, for use in packaging, transport, automotive, engineering and construction markets. The container products include rigid aluminium foil containers that are used for the catering industry and household use. Flow is regarded as an essential part of the system to help the organisation to achieve its targeted throughput and deliver material on time and in full to its customers [2]. Batch splitting and delayed material arrival at the destined machines for further processing in a specified sequence, are some of the reasons that lead to inefficiencies in the downstream machine centers. The aim of this study is to identify the root causes of inefficiency in coil transportation and develop measures to ensure proper flow of coils in the production system.

2 LITERATURE REVIEW

The principle of processing aluminium alloy sheet embraces understanding process parameters and the metallurgical effects from sheet ingot or slab casting, homogenisation, hot and cold rolling and annealing [3]. Papanagnou *et al.* [4] conducted a study where aluminium coils production process was modelled and simulated to improve throughput and makespan through timely decision making. The production process was divided into key steps that include scalping, hot rolling, annealing, cold-rolling, side trimming, stretching and degreasing. These steps can be divided into three key phases, the first phase includes delivery of slabs, scalping, hot-rolling and tandem mill process which take place in the Hot-Line shopfloor. The second phase includes integrates temporary storage, annealing and cold rolling processes, in the high-bay area. The last third phase includes levelling, stretching and degreasing, quality control and final storage.

Ganguly [5] used the DMAIC Six Sigma approach to improve the process for rolling mill to address the challenges that were being faced by an aluminium organisation. Considering its existing resources, the company was facing operational challenges when trying to cater to the fast-changing customised export demand for flat-rolled products. Hence, the study was aimed at developing hot rolling mill capability for wider widths hard alloys rolling and remove downtime emanating from strip slippage during hard alloys rolling during hot milling. The team identified the prevailing situation of the rolling mill operations and applying Six Sigma DMAIC methodologies to define the possible causes, identify the sources of variation, and established variable associations and implemented control plans.

Stamatis [6] explained Failure Modes and Effects Analysis (FMEA) as a logical, practical method for the evaluation of a process to ascertain where and how it might fail and as well assess the relative effect of diverse failure modes, with the view to establish the process elements that should be improved. FMEA is therefore characterised by the following steps; failure modes (establishing what could go wrong); failure causes (understanding what would cause the failure to happen); and failure effects (comprehending the consequences of each failure) [7, 8]. On the other hand, Khaloo *et al.* [9] posited that the key to success as well as a critical part of any health and safety programme is grounded on identifying, assessing, eliminating, and controlling hazards at the workplace. An environmental failure mode and effect analysis was employed to identify possible environmental risks, analyse the risks that characterised the environment, and established the highest risk priorities for the aluminium rolling industry.

Stamatis [6] proposed a novel methodology of measuring uncertainty for FMEA assessments and applied the improved model in sheet steel production to verify the reliability and validate the proposed method. Basing on the measure of ambiguity in the evidence theory, the uncertain degree of subjective assessment from FMEA experts was addressed. The uncertainty of FMEA assessment was then transformed into the weight of each FMEA expert and the respective

significance of each risk factor. More comprehensively, the assessment from different FMEA experts was thereafter fused through enhanced Dempster's rule of combination and the Gray Relational Projection Method was deployed to derive the ranking of failure modes to overcome the limitation of the traditional RPN-based ranking method.

On the other hand, Pancholi and Bhatt [10] investigated the failure of the aluminum wire rolling mill by using a gray-complex proportional risk assessment and preference section index. The study aimed to establish the extent to which the reliability of an aluminium wire rolling mill can be enhanced by utilising current maintenance and control practices. It was found that it is crucial to prioritise maintenance activities through comparative analysis of results that are derived from diverse failure analysis models.

3 METHODOLOGY

After gathering all the necessary problems concerning the current system as to its inefficiencies, the project was divided into different phases.

- Phase 1 - The current process was studied and represented on a flow diagram for simplification and to be able to visualize the process as a whole. A walk-through the plant was done to identify all the process steps.
- Phase 2 - The As-Is process that was documented in the first phase was then studied for errors and critical failure points and comments to each node were noted and validated against system users. The essence was to ensure and measure its impact on the flow of material and production in the company. The process flow with identified potential failure points were flagged as red stars to highlight possible Kaizen burst events.
- Phase 3 - A Failure Mode and Effect Analysis was implemented to document and analyse the failures and try to implement mitigating factors while also providing a control plan. This was made to ensure that the project would have a positive impact and beneficial to the company.
- Phase 4 - After all the investigation and data gathering, a new method was proposed in a form of a process flow to show some corrections and new changes that were to be introduced on the system. The demarcation were made for facility layout at Plant Z and the paint barcoding system.

4 CASE STUDY BACKGROUND

Coil Transportation is the process of moving the metal and lot tickets from one place to another for further processing (e.g. CDHM to Cold Mills or Coil Processing, S4 to Plate Plant). The manufacture of aluminium rolled products is characterised by coil transportation, which is a process of moving the metal and lot tickets from one point to another for further processing at other sub-plants. Coil transportation is vital for ensuring proper flow of coils in the production system, with flow regarded as the essential part of the system with regards to achieving manufacturing targets, delivering material on time and fulfilling customer orders. From the analysis, the indication is that the process is not meeting the primary targeted scheduled adherence of 100%, with an actual average of 52% in the last 3 months and not meeting the target number of between 80-100 coils per day, the percentage is 58%. The objective of the study is to clarify the measurements, indicate factors leading to the gaps and introduce the system to help standardize the process and extract KPI data to help manage this transportation activity. Figure 1 shows the graph of the trend of the coils sent from hotline to Plant Y (cold mills) over a month. The graph is a representation of the ratio between coils sent to Plant Y that were on the requested list as compared to the initial requirement in the list.

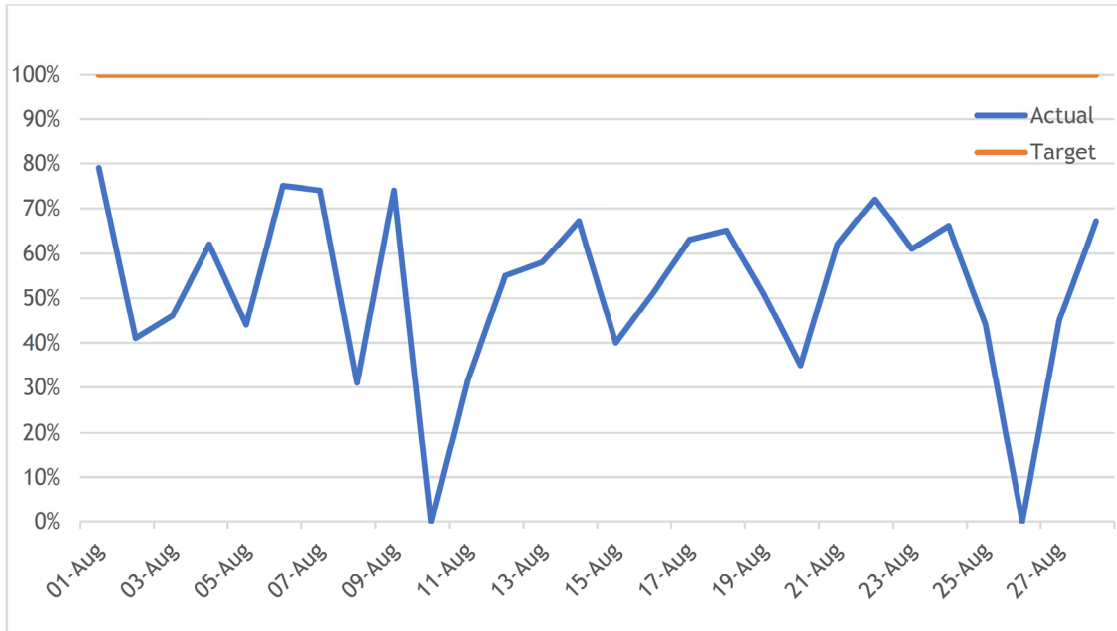


Figure 1: Trend showing the daily performed Adherence to Schedule for August 2019

5 RESULTS AND DISCUSSION

5.1 As-Is Flow critical failure points

The current method is a complicated and tedious process and biased, as it does not measure the rate at which the plant accommodates for delivery of coils. It also does not take into account major activities that might hinder the coil transportation e.g. shearing days (when the mill is occupied with rolling plates thicker than 15mm, the cranes and other supporting equipment get held up on that activity, other tasks like coil transportation do not happen in that period. This activity takes plus or minus twenty-four hours). The black boxed nodes clarify the failure points for each process node. Figure 2 shows the process flow with identified potential failure points shown as red 16 point stars highlighting possible Kaizen burst events.

The coil transportation system is manual, not reliable and human dependent; there are also not enough self-monitoring reports as it relies on individuals to record the information. The logistics coordinator receives the list of requested lots from the Plant Z sequencer. The logistics coordinator will also submit the list to the plant where the truck drivers locate the coils and lot tickets. The crane driver by the instruction of the coordinator and driver loads the coils onto the truck for dispatching to Plant Y, upon departure the truck driver records the exiting time onto the log sheet and records the arrival time when the driver reaches the destination.

The lot tickets are then placed onto the ticket box after delivery to be collected by a sequencer for scanning to confirm lot arrival. If there is, anything that becomes a problem in the system during the task the driver will manually record it on the rear of the log sheet. The log sheets are stored in a box for future reference or when they need to access past information regarding deliveries. Sequencers collect the lot tickets at different intervals for scanning.

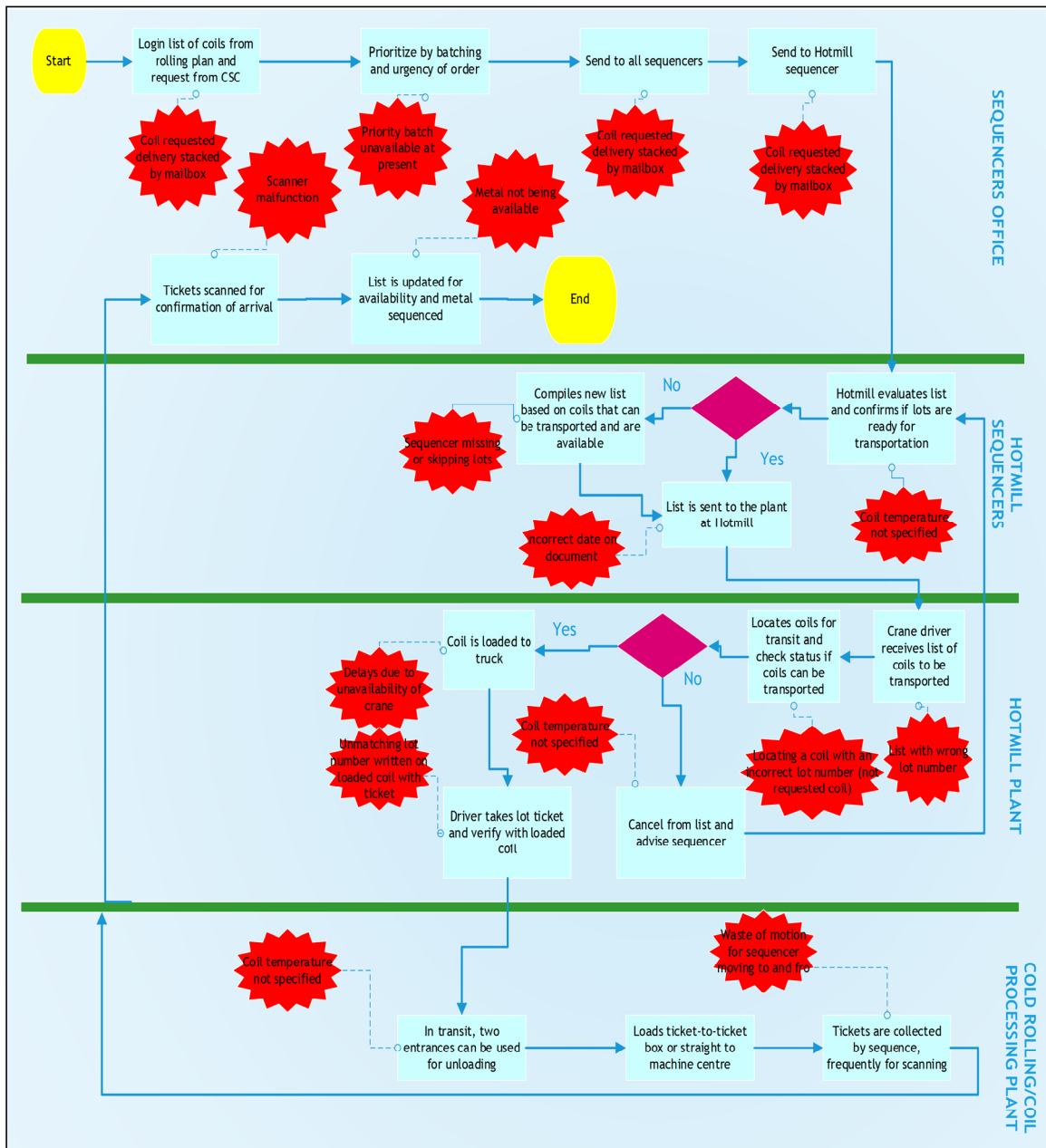


Figure 2: Process Flow with identified potential failure points

The major irregularities in the system include:

- Lack of communication between requester and receiver
- The system is people dependent
- No proper delay logging mechanism e.g. offloading delays
- The system is not mistake proofed thus exposed to mistakes/ human error
- Relies on individuals to generate reports for system usage
- Unable to produce reliable KPI's

The current system does not allow the full presentation to the business of the effectiveness of the process as it becomes difficult for individuals to agree on the measures because they are not measuring the same thing. The system is static and does not have proper KPIs to report to the business. Most of the coils requested are hot, not ready to be transported. The current system is not monitored, the data is not reliable because some of the coils requested are already on the destination requested to and some requested coils have problems from non-conformance report [11] and quality issues. Coils delivered current performance is recorded on an excel spreadsheet, which is updated by a human, of which sometimes it is not updated due to absenteeism.

5.2 Failure Modes and Effects Analysis

Table 1: Failure Modes and Effects Analysis

Process	Potential Failure Mode	Potential Effects of Failure	Mitigating action	Control Plan
Login a list of coils from the rolling plan	The list is too static and coil status might change	<ul style="list-style-type: none"> Coils with NCR might be transported Coils that may have been transported already might be on the request list 	<ul style="list-style-type: none"> Coils transported should not appear as available coils to be transported NCR coils should not be selected when compiling a request list 	System
Prioritise by batching and urgency of the order	Batching of unavailable coils to transport	Batches might break and increasing changeover on the next operating machine	Colour-code lots of the same batch to make them easier to spot if there is a deficiency	Have a min and max batching rules for the different specs
Send to all sequencers	Email stuck on outbox folder	Late arrival of email causing delays in the process	Update and send email via BES	Ensuring all participants have access to the coil transportation app
Send to Hotmill sequencer	<ul style="list-style-type: none"> Email stuck on outbox folder Inbox of recipient full 	<ul style="list-style-type: none"> Not receiving sequence on time Sending of coils without a proper batching quantity 	Send the coil request list via the coil transportation app	Ensure the members utilise the system by using KPIs for coil movement
Hotmill evaluates list and confirm if lots are available for transportation	Disturbance in lot planning request from Plant Y sequencer, thus machine might stand or more changeovers due to different incoming specs	Different specs lower machine throughput rate due to high changeovers	All sequencers must use the coil transportation app to streamline communication flow on requirements and availability of materials	Train users on the use of the coil transportation app and use of different codes for material
Crane driver receives list of coils to be transported	Outdated list sent to crane driver	Time lost due to searching of dispatched coils	Monitor device to view the requested list of coils in real time	Monitor must also be available to sequencer to ensure feasibility of coils requested and compliance of driver
Locates coil for transit and check the status of coil if it can be transported	Locating coil that does not fully match the requested lot number (not requested coil)	Unscheduled coils filling up space in the racks	Coils must have a bar code matching the lot ticket to the lot number and must be scanned for departure and arrival	Colour coded scanner to ensure correct transportation of material

Table 1 shows a summary of the Failure Modes and Effects Analysis. Concerning the list sent to the plant for Hotmill, it was noted that the list might be containing high-temperature coils, with

potential effects of failure which include delays in transporting coils, poor adherence to schedule, breaking of batches, and machine idle due to no work. The mitigating action would be to provide the shopfloor with a screen device to view the list on the coil transportation app, provide live data on the monitor for any changes in the batching arrangements, and enforcing the scanning of materials before sending to Hotmill.

It was also noted that the truck driver might load incorrect coils that do not match the provided lot ticket when the coil is loaded to a truck, thereby leading to delays in the batching system for the next operating machine, breaks the sequence flow. As a solution, coils must be clearly labelled for the truck driver to see, coils on the request list must be separately located, coils must have a bar code matching the lot ticket to the lot number, and the shopfloor members must monitor the process continuously from start to end.

5.3 Proposed Process

The proposed continuous improvement initiatives focus on four critical factors to be taken into account for the system and these include:

- The shift patterns for each department
- The number of vehicles available daily
- The time to load and unload coils
- The arrival and departure at the sites

Figure 3 shows the process flow diagram for the proposed systematic procedure and the change put more emphasis on how the coils are requested from/by the sequencer and how the process is carried until shop floor level. Using Outlook as the primary source for the process will be diluted by the introduction of an app that is/will be on BES to help fast track and fool-proof the process. The system that relied on the driver engaging in paperwork and will be subjected to change with the introduction of the scanners and stickers. The system will also fool-proof the transportation of the correct coil against the lot ticket.

The proposed transportation system will be embodied into the system thus communicating with its stated KPI's to provide a live fed in terms of the progress. Further designs and capabilities will be negotiated with relevant parties.

The driver must be able to scan each coil as it is placed on the tractor. The location of the metal must then become "INTRANSIT" and the time scanned reflected on to the system and logged. If the metal has an NCR the coil must restrict to be loaded on the requested list, in the event of the material changing status to becoming NCR, the operator must be warned and the coil should be taken out of the truck unless there are exceptions. This is to ensure that NCR'd material is not to be transported for further processing. When the driver is ready to leave CD he will scan it out as opposed to recording it on the log sheet, the time of departure is to be logged. When the driver delivers these tickets he will scan them against the coil as a confirmation that the coils have been delivered as opposed to signing in the log sheet. These will again serve as a confirmation that the correct coil with the correct lot ticket has been delivered to the right destination. The delivered coil will then be automatically removed from the transportation list on the app. As soon as the driver scans the last coil a trigger is sent to the loading bay indicating an incoming truck for loading. The process will continue as indicated for further deliveries.

The sequencer must be able to access the daily WIP on the app at BES same as in Oracle Discover (WIP INVENTORY). The sequencer must toggle the list up and down until the desired effect and save plus approve. The driver must be able to scan each coil as it is placed onto the trailer. The location of the metal will change to reflect in transit on the system/app and the time scanned recorded. A sticker should be printed and attached to the lot ticket indicating the next machine and other useful details. Metal containing an NCR will be identified using a different color on the system and it should restrict being loaded to the list.

Should a material status change the information will be updated onto the system and the driver will be warned and he must remove the coil from the trailer, thus ensuring that no NCR'd metal is transported for processing. The system must be uploaded with standard times for all the different activities to enable auto delay trigger should activities last longer than the allowed time.

The coils must be scanned as soon as they arrive by the driver to change the status to delivered in the system and again put to the ticket box.

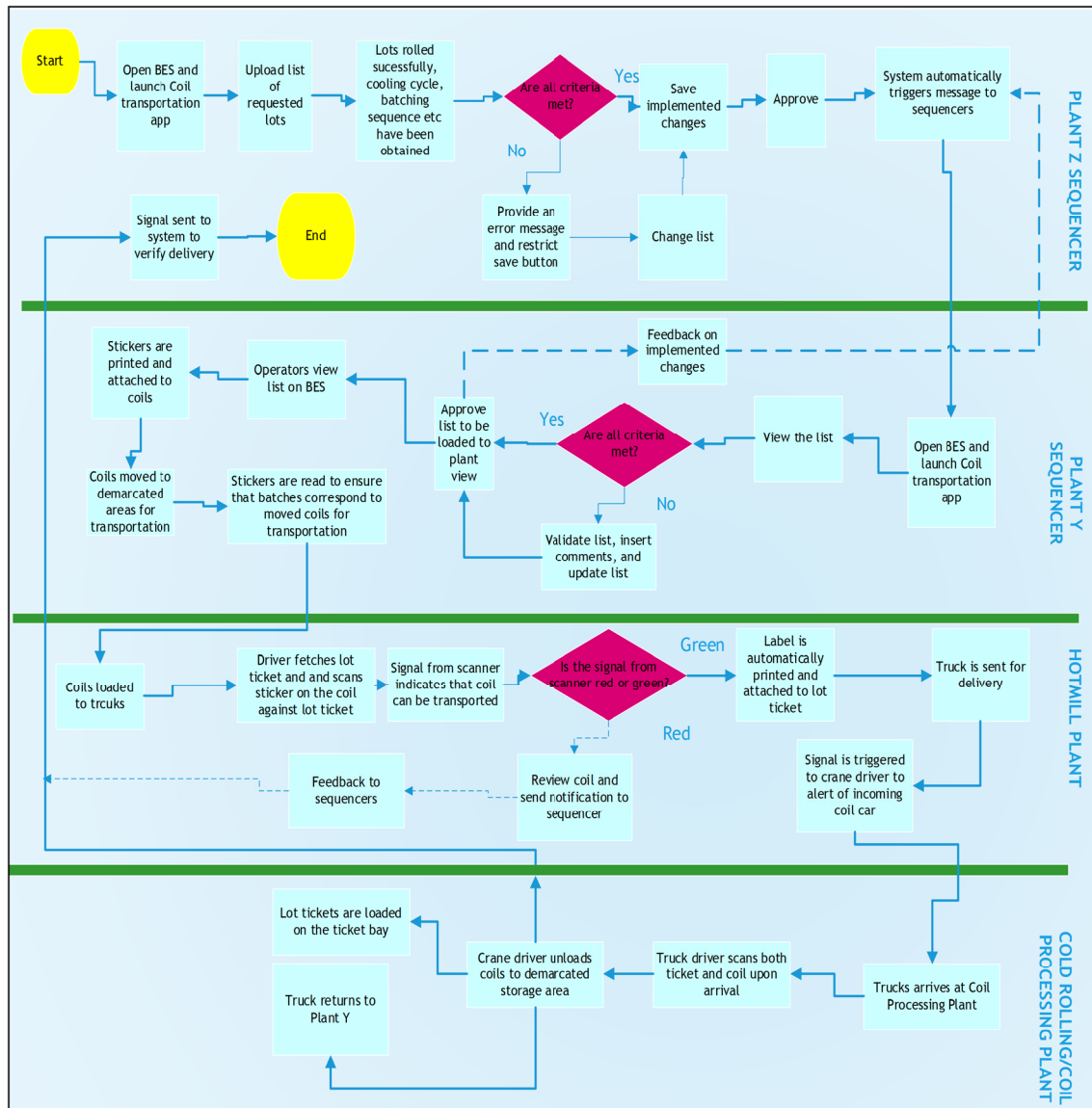


Figure 3: Process Flow showing the proposed systematic procedure

The snag list for coil transportation app would include the following:

- Dispatched lots remain within the system
- There must be color-coding on the system to easily visualize the lots with different statuses e.g. temperature whether the metal is cool or still in the cooling process
- There is a need for two different views of the system as opposed to the current single view
- The system must be able to move or allow the user to drag and drop lots in the system

5.4 Summary of benefits from proposed changes

Table 2 shows a comparison of the scenario before continuous improvement initiatives and after the implementation of proposed changes. The results demonstrate an improvement of schedule adherence from 58% to 80%. The average coil lead time also reduced from 3 hours to 2.2 hours due to elimination of errors such as locating a coil with an incorrect lot number (not requested coil) and reducing waste of motion for sequencers.

Table 2: Comparison of before-and-after continuous improvement initiatives

Parameter	Before continuous improvement initiatives	After implementation of proposed changes
Scheduled adherence	58%	80%
Average coil lead time	3 hours	2.2 hours

6 CONCLUSION

There is always room for improvement of material handling system for coil transportation in the manufacture of aluminium rolled products. FMEA is a handy industrial engineering tool that can be deployed to assess the relative effect of diverse failure modes, with the view to establish the process elements that should be improved. The system was performing at 58% against the targeted 100% due to the systematic manner by which the request was sent through from Plant Y to Plant Z and how the information is filtered through to the shop floor for execution. The BES system was installed and the compliance to the schedule improved from 58% to 80% by end of the year. Facility layout and Paint Barcoding system at Plant Z are the other phases which are part of work-in-process to be completed. The implementation of the coil transportation project was beneficial because it fostered teamwork. The team had to pay attention to detail and identified the root causes of inefficiency in coil transportation and developed measures to ensure proper flow of coils in the production system.

REFERENCES

- [1] M. Krieg, "Focus on: South Africa," *Aluminium International Today*, vol. 29, no. 3, pp. 6-8, 2017.
- [2] A. Gunasekaran, C. Patel, and E. Tirtiroglu, "Performance measures and metrics in a supply chain environment," *International journal of operations & production Management*, 2001.
- [3] J. Hirsch, "Aluminium sheet fabrication and processing," in *Fundamentals of Aluminium Metallurgy*: Elsevier, pp. 719-746, 2011.
- [4] C. I. Papanagnou, P. Tzionas, and C. Xanthopoulos, "Modelling and simulation of aluminium coils production process using coloured petri nets," in *Proceedings of the 6th Eurosim congress on modelling and simulation. Ljubljana, Slovenia, 2007*.
- [5] K. Ganguly, "Improvement process for rolling mill through the DMAIC six sigma approach," *International Journal for quality research*, vol. 6, no. 3, pp. 221-231, 2012.
- [6] D. H. Stamatis, *Failure mode and effect analysis: FMEA from theory to execution*. Quality Press, 2003.
- [7] Z. Wang, J.-M. Gao, R.-X. Wang, K. Chen, Z.-Y. Gao, and W. Zheng, "Failure mode and effects analysis by using the house of reliability-based rough VIKOR approach," *IEEE Transactions on Reliability*, vol. 67, no. 1, pp. 230-248, 2017.

- [8] N. Xiao, H.-Z. Huang, Y. Li, L. He, and T. Jin, "Multiple failure modes analysis and weighted risk priority number evaluation in FMEA," *Engineering Failure Analysis*, vol. 18, no. 4, pp. 1162-1170, 2011.
- [9] S. S. Khaloo, R. Saeedi, and A. Sanjari, "Environmental risk assessment and corrective measures for the metal rolling industry," *Environmental monitoring and assessment*, vol. 191, no. 9, pp. 1-13, 2019.
- [10] N. Pancholi and M. Bhatt, "FMECA-based maintenance planning through COPRAS-G and PSI," *Journal of Quality in Maintenance Engineering*, 2018.
- [11] F. P. Incropera, D. P. DeWitt, T. L. Bergman, and A. S. Lavine, *Principles of heat and mass transfer*, 7th ed. (no. Book, Whole). Hoboken, NJ: Wiley, 2013.