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AVAILABILITY STUDY IN AUTOMATED AND SEMI-AUTOMATED PRODUCTION LINES TO HELP WITH PRODUCTION RAMP AND SUSTAINABILITY

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Abstract

The automotive industry is experiencing rapid growth and evolution, with a focus on production ramp-ups and sustainability. To meet these demands, manufacturers are increasingly turning to automated or semi-automated production lines. However, maintaining high production availability in such complex systems is crucial for meeting ramp targets and ensuring sustainability. This paper presents a comprehensive study on availability in automated and semi-automated production lines, highlighting key factors, challenges, and strategies for improving availability to support production ramp and sustainability goals. Through data-driven approaches and station-state analysis, manufacturers can optimize line performance to meet both production and sustainability objectives. This paper outlines fundamental PLC logic for capturing start and stop times to collect data on key parameters such as running time, starved time, blocked time, fault time, and manual time. These parameters are crucial for generating charts that identify inefficiencies and bottlenecks within production lines. By leveraging lean principles like takt time and process time, this approach enables manufacturers to analyze and optimize production performance, ensuring efficient operations and improved throughput.

Keywords: Production Ramp, Automated Production Line, Semi-Automated Production Line, Availability, OEE (Overall Equipment Effectiveness), Sustainability, Production Bottlenecks, Takt Time, Process Time, Fault Time, Starved Time, Blocked Time, Station state analysis, Efficiency, Manufacturing Systems, Throughput Optimization, Continuous Improvement.

I. INTRODUCTION

The automotive industry is undergoing a transformation driven by technological advancements, changing consumer preferences, and environmental policies. As a result, manufacturers are adopting automated or semi-automated production lines to improve efficiency, quality, and sustainability. However, ensuring high availability in these systems is critical for meeting production ramp targets and achieving sustainability goals. Availability, defined as the percentage of time that a system or machine remains operational, is a key metric in calculating OEE (Overall Equipment Effectiveness). High availability is essential for meeting

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production targets, minimizing customer wait times, and maximizing equipment utilization. This paper deep dives into ways to identify opportunities to improve the throughput of a production line using a data-driven approach. Also, dwells on using similar methods to identify the line bottlenecks to identify opportunities to improve the target production.

II. DEFINITIONS

A. Cycle time:

The time required per part/job to complete the operation in the manufacturing process. This can be obtained using simple methods like a stopwatch or through theoretical standards like MODAPTS, MOST, etc

B. Takt Time:

The target cycle time per part/job to meet customer demand. Takt time serves as the heartbeat of the production line, determining the production capacity during the development phase.

C. Process Time or Running Time:

The time when a machine or process is actively running and producing output. To meet the customer demand process time is required to be less than takt time, otherwise, the number of stations/machines needs to be higher than 1.

D. Starved Time:

When a machine or process is available to operate but is not running due to lack of input to produce output.

E. Blocked Time:

When a machine or process is unable to operate due to a blockage by a machine or process downstream or in other words if the station completes the process at the station and is unable to release the part to the next station due to the station downstream not being ready.

F. Fault Time:

When a machine or process is stopped or halted due to a fault or malfunction.

G. Manual/Stop Time:

When a machine or process is manually stopped for maintenance, adjustment, or other reasons.

III. Overall Equipment Effectiveness (OEE)

OEE is a measure of how a manufacturing operation is utilized compared to its full potential, calculated as the product of availability, performance, and quality.

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A. Components of OEE:

1. All Time:
Theoretically, this is a 24/7 time of the week.

2. Planned Production Time & Schedule Loss:
Planned production time is the time that is intended to meet the customer demand. Usually, it is 5 days 24 hours per day, this could vary based on the designed capacity of the production line. Scheduled loss is all time minus planned production time, in other words, this accounts for the planned maintenance/overhaul time and planned downtime.

3. Run Time (up-time) & Availability Loss:
Run time, also commonly known as uptime is the time while the production line produces output. Availability loss, also commonly known as unplanned downtime, accounts for when the production line is planned to run but fails to produce output due to various reasons like equipment failure, material shortage, etc.

4. Net Run Time & Performance Loss:
Net Run Time is time utilized to produce output based on the performance of the equipment and/or manual labor. The performance loss is the time lost caused by the performance of the equipment and/or manual labor, or Run Time minus Net Run Time.

5. Fully Productive Time & Quality Loss:
Fully Productive Time accounts for the time the production line produced the parts that meet defined quality standards without reworking. Quality loss accounts for the time the production line produces non-conforming parts.

B. OEE Calculation:

$$OEE = 1 - \left[\frac{Availability\ Loss\ X\ Performance\ Loss\ X\ Quality\ Loss}{Planned\ Production\ Time}\right]$$

IV. SYSTEM SETUP AND DATA COLLECTION
There are multiple ways to collect data from an automated line. Programmable logic controllers (PLCs) can be programmed to log data for each station such as running time, starved time, blocked time, fault time, and manual stop time. These metrics can be used to identify bottlenecks during production ramp-ups or to detect inefficiencies. Data can be analyzed in tools like Excel or visualized in real-time through Power BI or Snowflake to monitor line performance.

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A. Identifying Production Inefficiencies:

Identification of production inefficiencies is crucial while spearheading the ramp of a production line. I want to focus on how one can identify the losses to identify the availability losses and performance losses of the equipment. In this case, the key information needed from each station is based on Part-to-Part cycle time data, in other words, the lap time starts when a part enters the station and ends when the next part enters the station. Takt time should be used to reference the decision in the PLC logic to define the Running time, Starved Time, and Blocked Time.

1. PLC Logic:

In case of identifying inefficiencies, the PLC logic for the following parameters can be used as follows for the start and end of each of the following time metrics, if needed, revisit the logic after the example stated following the logic description:

- Running Time:

Start Time Logic: Time starts when the job enters the station.
End Time Logic: Time stops at the end of takt time or the start of the next cycle.

- Starved Time:

Start Time Logic: Time starts if the Running time exceeds takt time but the next job does not arrive at the station to start processing.
End Time Logic: Time stops when the next part arrives at the station to start the next cycle.

- Blocked Time:

Start Time Logic: Time starts if the process is complete but the station remains blocked over the takt time.
End Time Logic: Time stops when the next part arrives at the station to start the next cycle.

- Fault Time:

Start Time Logic: Starts at the start of the faulted state.
Ends Time Logic: Time stops when the fault is cleared or acknowledged.

- Manual Time:

Start Time Logic: Starts when an auto operation is switched to manual mode.
Ends Time Logic: Ends when the station is switched back in Auto mode.

2. Example:

I would like to demonstrate the above logic using an example of an event on an automated production line, let’s assume it has 10 stations in a one-piece-flow system, for simplicity's sake, also, let’s assume we are analyzing data of a production run for 100 minutes and has an occurrence of 1 unplanned downtime event. I will use this to describe how the chart for the

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above logic should help you identify the losses.

3. **Event Description:**

There is a downtime event at station no. 5, the event starts with a fault, and station no. 5 remains faulted for 5 minutes while engineers and technicians are troubleshooting the issue. The issue was then identified and a technician entered the station by switching the station to manual mode using the LOTO process for 15 minutes, the issue was then resolved and the station was recovered or switched to auto mode.

The graph below [Fig 1.1] represents the event at station 5 with the description of the 5-minute faulted time and 15-minute manual time. Since the line is based on a 1-piece flow the stations upstream will be blocked for 20 mins and the station downstream will be starved for 20 mins. The running time will be the same through all stations on the line, this determines the uptime of the line. The chart below represents 80% uptime or availability through this event. The state analysis chart can be a strong and effective tool in identifying the focus areas based on the faulted and manual state when dealing with hundreds of such events weekly to then further drive corrective actions.

In real case scenarios one shall produce these graphs with a cumulative result of hundreds of such events over a set period. In ideal case scenario see below [Fig 1.2] with 100% availability the graph should show all stations with green.

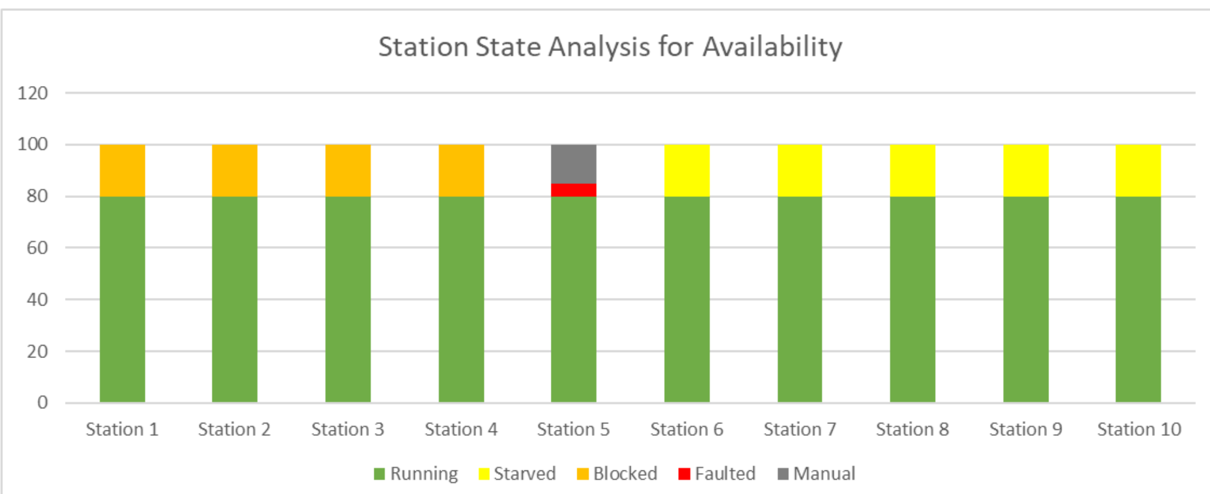

Fig. 1.1: With 80% Availability

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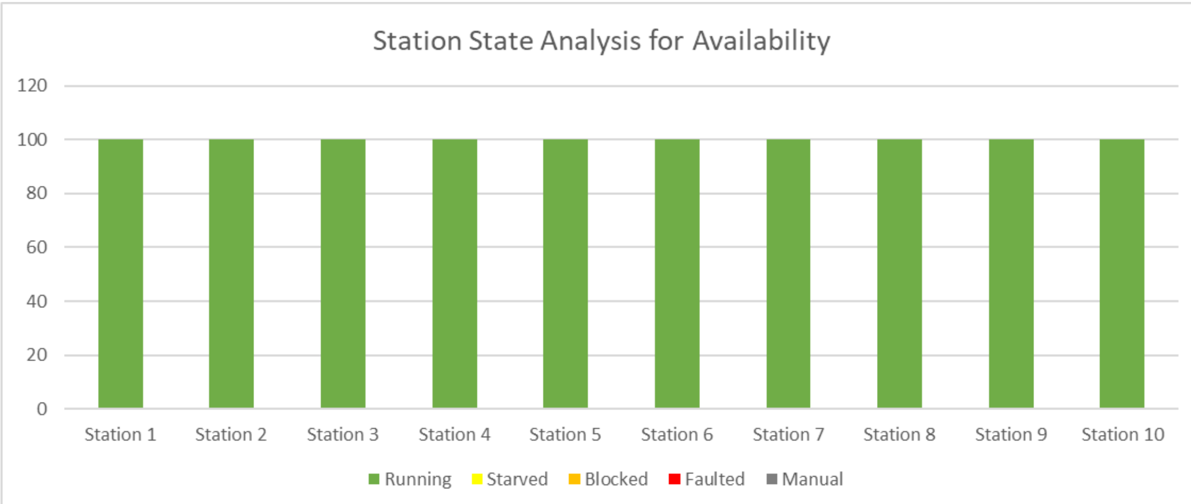

Fig 1.2: at 100% Availability

B. Identifying Production Bottleneck:

In recent market scenarios, with extensive innovation and production development, rapid ramping up a production line has become ever more critical, and necessary. Also, supply and demand have been significantly fluctuating due to various reasons, like supply chain disruption, geo-political instabilities, new product unveils and launches, and changing industry dynamics from gas to hybrids and BEV. This drives the manufacturing focus to manipulate the production targets to fulfil the high and low market demands. There are many ways to react to the low demand, like, reducing the overtime production hours if any, and scheduling planned downtimes for preventative maintenance and operator training. In the case of high demand forecast, identifying the bottleneck is very important to increase the capacity of the production line, in efforts to increase the target JPH (jobs per hour). The key difference here is that the processing time of the stations is used instead of the takt time to define the running time, starved time, and blocked time.

1. PLC Logic:

In case of identifying bottleneck, the PLC logic for the following parameters can be used as follows for the start and end of the times:

- Running Time:

Start Time: Time starts when the job enters the station.
End Time: Time stops at the end of the process or the start of the next cycle.

- Starved Time:

Start Time Logic: Time starts if the Running time exceeds processing time but the next job does

not arrive at the station to start processing.
End Time Logic: Time stops when the next part arrives at the station to start the next cycle.

- Blocked Time:

Start Time Logic: Time starts if the process is complete but the station remains blocked after the processing is complete.
End Time Logic: Time stops when the next part arrives at the station to start the next cycle.

- Fault Time:

Start Time: At the start of the faulted state.
Ends Time: Ends when the fault is cleared or acknowledged.

- Manual Time:

Start Time: When an auto operation is switched to manual mode.
Ends Time: When the station is switched back in Auto mode.

2. Example:

I would like to use the same example from the production inefficiencies section above to demonstrate this case. I have assumed the same 10 stations with 100 mins production run and 1 downtime event with 5 min faulted and 15 min manual mode. Assuming every station has a different process it may likely have different process times.

3. Event Description:

I will use the same event from production inefficiencies section where we focused on an application using takt time to chart the station state analysis. The downtime event is at station no. 5, the event starts with a fault, and station no. 5 remains faulted for 5 minutes while engineers and technicians are troubleshooting the issue. The issue was then identified and a technician entered the station by switching the station to manual mode using the LOTO process for 15 minutes, the issue was then resolved and the station was recovered or switched to auto mode.
The graph below [Fig 2.1] displays the event caused at station 5 with faulted and manual time on station 5 while impacting the blocked time and starved states on upstream and downstream stations respectively. The values of blocked and starved states are different since the running time is fetched based on the processing time. The area to focus is running time which helps identify the bottleneck of the line in this case with highest running time at station 7 is the bottleneck of the line.
In ideal case scenario see below [Fig 2.2] all station before bottleneck station shall show some % of blocked state while station downstream should show some % of starved state. This charting of state analysis is helpful while ramping up a production line to identify bottleneck and so the resources can be invested in well-prioritized continuous improvement projects.

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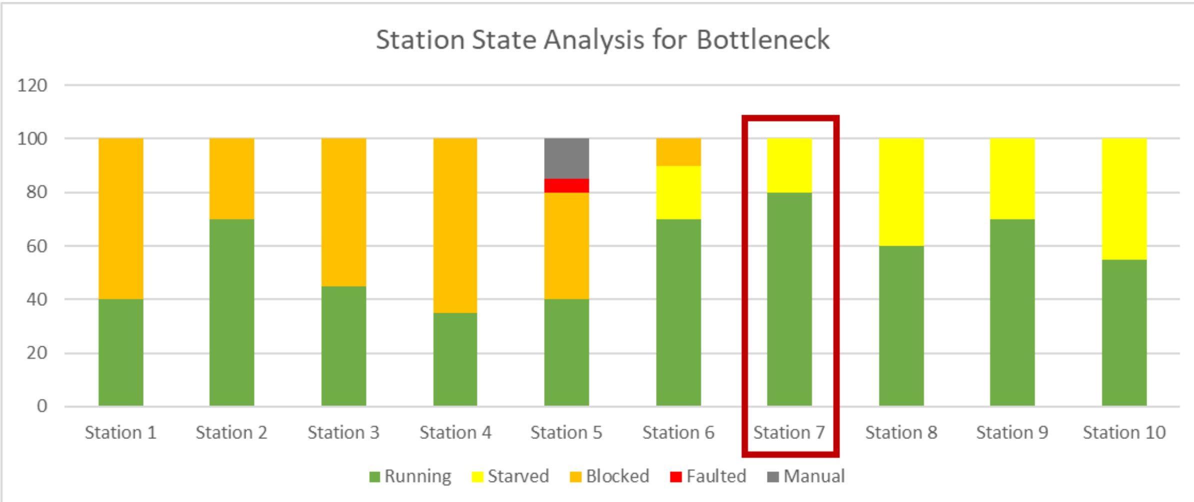

Fig 2.1: With 80% Availability

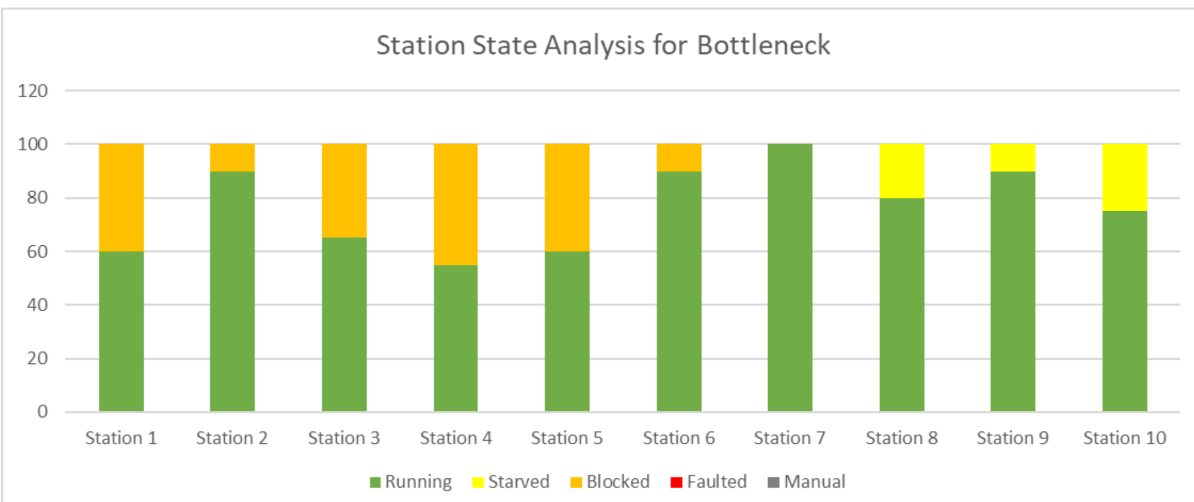

Fig 2.2: With 100% Availability

IV. CONCLUSION

The newly automated lines can be optimized for production by utilizing station state data collection through logic based on takt time to identify inefficiencies, and process time to pinpoint bottlenecks within the production line. By leveraging this data-driven approach, manufacturers can enhance the performance and throughput of automated systems, ensuring smoother production ramp-ups and greater overall efficiency. This method allows for targeted improvements that can reduce downtime and streamline operations. Additionally, it provides valuable insights into equipment performance, helping organizations prioritize continuous improvement efforts and maximize the productivity of their automated production lines.

REFERENCES

1. Lean Production, "OEE Overview," Lean Production. [Online]. Available: https://www.leanproduction.com/oee/. (accessed Aug. 11, 2023)
2. Worximity, "What is OEE (Overall Equipment Effectiveness)?," Worximity Blog, 2023. [Online]. Available: https://www.worximity.com/blog/what-is-oee-overall-equipment-effectiveness. (accessed Aug. 11, 2023)
3. OEE, "OEE Factors," OEE. [Online]. Available: https://www.oee.com/oee-factors/. (accessed Aug. 11, 2023)
4. OEE, "Calculating OEE," OEE. [Online]. Available: https://www.oee.com/calculating-oee/. (accessed Aug. 11, 2023)
5. OEE, "How to Calculate Takt Time," OEE. [Online]. Available: https://www.oee.com/takt-time/how-to-calculate/. (accessed Aug. 11, 2023)
6. OEE, "Cycle Time," OEE. [Online]. Available: https://www.oee.com/takt-time/cycle-time/. (accessed Aug. 11, 2023)
7. V. Deshpande, P. S. Wakode, and S. S. Mantha, "Analysis of the Overall Equipment Effectiveness (OEE) to Minimize Six Big Losses of Pulp Machine: A Case Study in Pulp and Paper Industries," Procedia Engineering, vol. 38, pp. 198-202, 2012. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1877705812022606.
8. M. Muhamad, and H. A. Mohd Zulkifly, "Analysis of the Overall Equipment Effectiveness (OEE) to Minimize Six Big Losses of Pulp Machine: A Case Study," ResearchGate. June 2019 [Online]. Available: https://www.researchgate.net/publication/333684018_Analysis_of_the_Overall_Equipment_Effectiveness_OEE_to_Minimize_Six_Big_Losses_of_Pulp_machine_A_Case_Study_in_Pulp_and_Paper_Industries.
9. S. Nakajima, "Introduction to TPM: Total Productive Maintenance," Productivity Press, 1988.
10. M. Rother and J. Shook, "Learning to See: Value Stream Mapping to Create Value and Eliminate Muda," Lean Enterprise Institute, 1998.
11. J. P. Womack, D. T. Jones, and D. Roos, "The Machine That Changed the World: The Story of Lean Production," Free Press, 1990.
12. M. Holweg, "The Genealogy of Lean Production," Journal of Operations Management, vol. 25, no. 2, pp. 420-437, 2007. [Online]. Available: https://doi.org/10.1016/j.jom.2006.04.001.
13. A. K. Sahoo, P. Tripathy, S. K. Sharma, and R. K. Shadangi, "Overall Equipment Effectiveness Improvement of a Manufacturing System," International Journal of Industrial Engineering Computations, vol. 6, no. 1, pp. 119-134, 2015. [Online]. Available: https://doi.org/10.5267/j.ijiec.2014.9.003.
14. T. Phillips and J. T. Black, "Lean Engineering," Virtualbookworm Publishing, 2013.