FAB DELIVERY SYSTEM OPTIMIZATION - UNDERSTANDING RELATIONSHIP BETWEEN FACTOR WEIGHTS ON PRODUCTION WAITING TIME USING SIMULATION BASED SCHEDULING SYSTEM

DEPARTMENT OF INDUSTRIAL SYSTEMS AND ENGINEERING MANAGEMENT
IE3100M SYSTEMS DESIGN PROJECT AY 2019/2020

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PROJECT OVERVIEW

BACKGROUND

- Micron's fabrication plants is currently using a Scheduling System, a machine specific dispatching system to determine the priority of wafer lots during its manufacturing process.
- Due to a large number of wafer lots and limited equipments available, it results in a buildup of Work-In-Progress (WIP) wafer lots, and hence inefficiency in the production.
- To purpose of the Scheduling System is to determine the priority of the wafer lots such that the production waiting time is reduced.

PROBLEM DESCRIPTION

- The Scheduling System makes use of a 'Priority Score' to determine the priority of wafer lots during its production. The higher the priority score of a wafer lot, the earlier it will be dispatched for processing.
- Priority score of lot is the product sum of all:
  1. Attributes: lot characteristics, such as queue time or age of lot.
  2. Factor Weights: which determines the significance of each attribute.
- Priority Score Formula:

$$\text{Priority Score of a Lot using Preset } X = \sum_{i=1}^{n} (\text{Attribute}_i \times \text{Attribute Factor Weight}_{Xi})$$

where: Attribute_i = value of attribute i for the lot,

$\text{Attribute Factor Weight}_{Xi}$ = Value of Factor Weight for Attribute i in Preset X

- Factor weights are extremely crucial in lot scheduling: the way the factor weights are set can determine the priority of lot scheduling, and affecting the efficiency of the production process.
- Currently, the value of the factor weights are set based on fab operators' past experiences and intuition which is ungrounded in any scientific data.

CURRENT METHOD BY MICRON

- To forecast the performance of the Scheduling System, Micron utilises a simulation based Scheduling System.
- The simulation system requires operators to input the value of the factor weights. Subsequently, simulation will be run and the results will be generated in the form of a 'Simulation Gantt' as the output.
- A Simulation Gantt shows the detailed scheduling decisions that will be made in the next 24 hours by the Scheduling System.

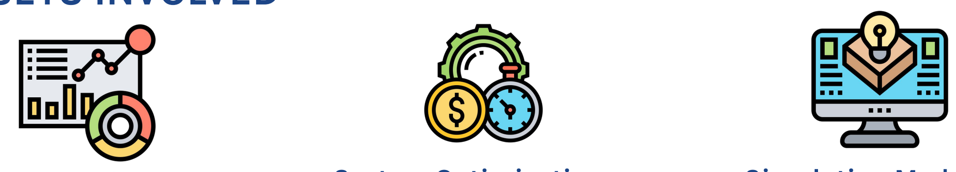
PROJECT OBJECTIVE

1. To study the relationship between the weighted factors and the performance of the Scheduling System.
2. The findings would serve as an initial step for the development of a framework that can assist Micron operators in Fab10N in deciding the optimized values to assign the factor weights, such that the performance of the Scheduling System is maximized.

PROJECT SCOPE

1. **Wafer type:** This project focuses on a single type of wafer, the C7N wafer, one of Micron's latest type of wafer.
2. **Factor Weights:** A set of key factors that will critically affect the scheduling decisions for C7N will be identified and studied.

SKILLSETS INVOLVED



PROJECT METHODOLOGY

STEP 1: PROBLEM ANALYSIS
- **Understanding the Complexities of the Scheduling System**

STEP 2: PROBLEM BREAKDOWN
- **Removal of Anomalies**
- **Categorisation of Process Steps**

STEP 3: INVESTIGATION
- **Identification of Critical Factors**

STEP 4: Testing
- **Conduct Sensitivity Analysis**

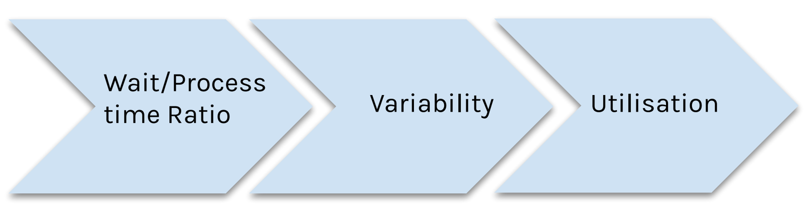
STEP 5: Results
- **Evaluation of Results**
- **Limitations and Future Improvement**

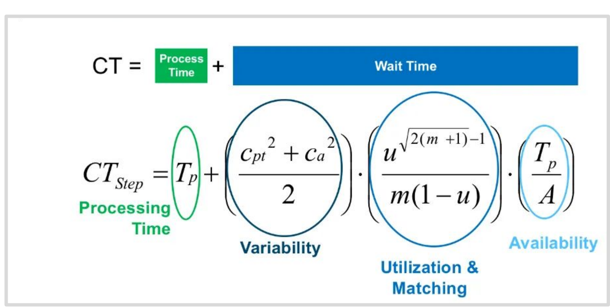
ASSUMPTIONS

- Data in the top 10% in terms of X Factor in a single simulation gantt includes **all anomalies**.
- The process time of **all process steps** are relatively constant throughout all models.
- The classification of the process steps into different categories in terms of their process time allows a **fair investigation** of the most problematic process step.

INVESTIGATION

PROBLEMATIC INDICATOR USED:





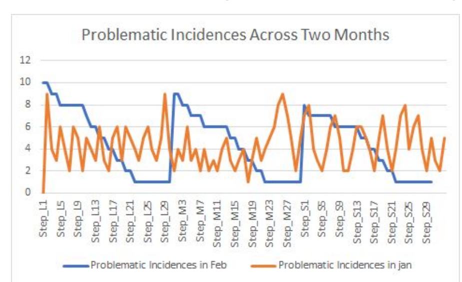
- Since wait/process time ratio indicator is denominator sensitive, process steps were categorized into long, medium and short in terms of their process time to ensure fair analysis.
- The three indicators will allow us to identify the problematic steps, and hence to select the set of critical factors to focus on.

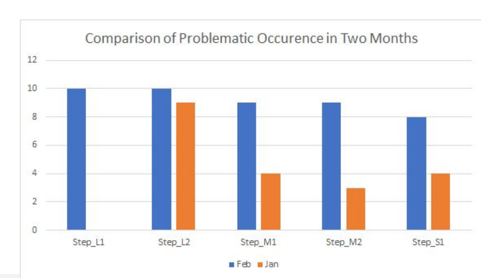
DATA CLEANING

- Data in the top 10% in terms of X Factor were removed to account for anomalies. As seen below, the data resembles a normal distribution more after data cleaning.

DATA ANALYSIS

- Steps with consistently above average wait/process time ratios and variability are identified across 480 hours of data taken across two months.
- Microsoft Excel and RStudio was used to perform data analysis.
- Top 10 problematic steps in each category are identified using 10 models from February. To verify that these steps are truly problematic, 10 models from January were also analysed.





- From the results, **STEP_L2** showed persistent problematic nature in both February and January. Hence, we select **STEP_L2** as the most problematic step for further analysis.

IDENTIFICATION OF RELATED FACTOR WEIGHTS

- Further investigation reveals that the equipment responsible for performing **STEP_L1** have **PRESET_L1** as their factor preset.
- 18 weighted factors are associated with **PRESET_L1**.
- With this findings, we have identified the set of key factors that will critically affects the scheduling decisions for C7N wafer lots.

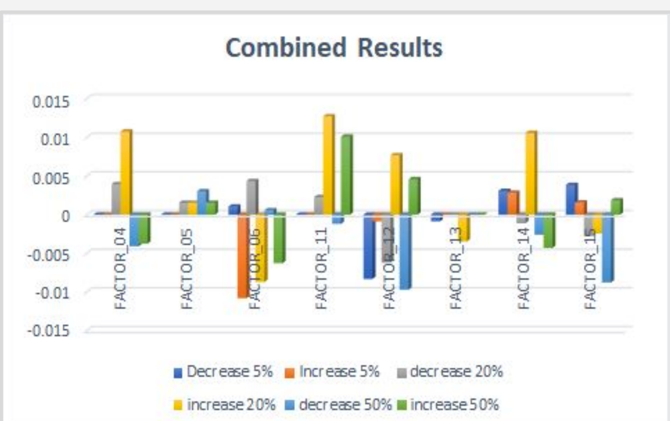
TESTING

- Each factor was singularly adjusted by various degrees across 10 models in February.
- Simulation runs were conducted iteratively after each factor weight adjustment, and RStudio was used to compute the waiting time of each Simulation Gantt produced.
- Subsequently, the percentage improvement in the waiting time of C7N wafer lots are calculated.
- By performing the adjustment and analysis process iteratively for all factor weights, we are able to investigate how the changes in the factor weights affect the waiting time of C7N wafer lots, thus achieving the project objective.

RESULTS AND DISCUSSION

COMBINED RESULTS

- Changes were made to all 18 factors
  - ±5%, ± 20% and ±50% from their default values.
- 3240 minutes of simulation runs and 20,736 hours of data were analysed.



- These top three changes that will result in the highest decrease in overall production waiting time of C7N wafer lots, namely:
  - 20% increase in **FACTOR_11** (1.27% reduction in waiting time)
  - 20% increase in **FACTOR_04** (1.08% reduction in waiting time)
  - 50% decrease in **FACTOR_14** (1.06% reduction in waiting time)

SIGNIFICANCE OF RESULTS

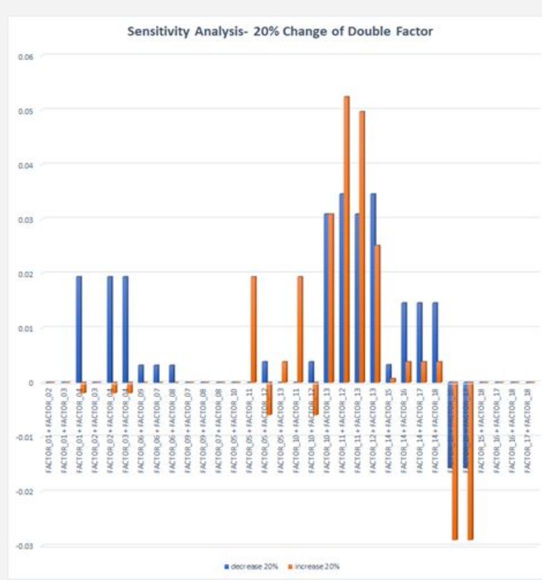
- The total waiting experienced by C7N wafers in a single simulation gantt of 24 hours is approximately 180,000 minutes.
- A 1.27% reduction will mean that a total of **approximately 2280 minutes of collective waiting** experienced by all C7N wafer lots is saved per day.

FURTHER ANALYSIS - MULTIPLE FACTOR CHANGE

- The next natural question to ask was: would making all these changes simultaneously create an even more significant improvement than single factor changes alone?

	Accumulated Waiting Time		
Model	**Default**	**Top 3 Changes**	**Top 2 Changes**
144327	10519336	10511763	10315182
145743	10802411	10623116	10456555
163751	10550551	10471970	10550551
165126	11382469	11444342	11466810
Average Accumulated Waiting Time	10813691.75	10762797.75	10697274.5
% Improvement	-	0.004706441	0.010765727

- The results showed that making the top three single-factor changes together and making the top two single-factor changes together will result in an average improvement of production waiting time of only 1.08%, lower than the improvement by **FACTOR_11** alone.
- This led the team to hypothesize that, when making multiple weighted factors changes, there is a need to consider interactions between the factors.
- To verify our hypothesis, we conducted double factor changes and analyzed the results.



- Sensitivity Analysis - 20% Change of Double Factor shows that the **combination of FACTOR_11 and FACTOR_12,** and the **combination of FACTOR_11 and FACTOR_13** yield highest positive improvement in overall production waiting time of C7N wafer lots by **around 5%**.
- Sensitivity Analysis - 50% Change of Double Factor shows that the **combination of FACTOR_06 and FACTOR_09, the combination of FACTOR_06 and FACTOR_07,** and the **combination of FACTOR_06 and FACTOR_08** yield highest positive improvement in overall production waiting time of C7N wafer lots by **around 4%**.
- In both settings, we observed that some of the changes that were previously non-critical in the Single Factor Change analysis, became critical in the Double Factor Change analysis.
- The results highlights the possibility that interactions between changes in weighted factors play a significant role when making multiple factor changes.

LIMITATIONS

- The team was only able to analyse data from a limited number of models and was unable to perform a very high number of simulation runs due to lack of computational power and time constraints.
- Results of this study may not be generalizable to all time periods as there are changes in demands and bottlenecks in different months.

CONCLUSION & FUTURE DIRECTION

- The optimization of lot dispatching rules can aid in production scheduling decisions and reduce waiting time of wafer lots.
- Significant improvements in waiting time has been found in this study when making these changes have been implemented using simulation.
- Future studies can look into:
  - More multiple factor weight adjustments instead of singular changes.
  - Comparing the efficacy of different lot dispatching rules such as fab-wide dispatching rules or fluctuation smoothing policies with the current usage of a machine specific dispatching rule using factor weights and attributes.