VALUE STREAM MAPPING (VSM) ON MAP AVAILABILITY AT INCOMING QUALITY CONTROL (IQC) PHASE: A LEAN APPROACH TO LEAD TIME REDUCTION AND MANUFACTURING EFFICIENCY IMPROVEMENT

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ABSTRACT

This abstract focused on using Value Stream Mapping (VSM) to enhance Wafer map availability at the Incoming Quality Control (IQC) step. Wafer Maps from Crolles (including AOI-3 and OQC maps) play a crucial role in the IQC process, as they provide vital information on wafer map defects encountered at Crolles. The objective of this research is to analyze the current map availability process, identify tailbacks, and propose improvements through the application of VSM principles.

Findings reveal that the IQC step experiences delays due to inadequate map availability, resulting in longer lead times and increased non-conformances. The VSM analysis uncovers root causes such as inefficient map retrieval methods, poor communication medium from the Wafer Fab site, and delays in wafer map updates.

To address these issues, the study proposes a set of countermeasures to improve map availability in IQC. These countermeasures involve the creation of an automated system that will extract the FAB Ink Map from the DIGS Server onto the Calamba Server, the creation of an automated system that will merge the FAB Ink Map with the AOI-3 map, standardized communication protocols, and enhanced collaboration between responsible personnel for map creation and updates.

The projected outcomes of the improvements are expected to lead to reduced lead times, decreased non-conformance rates, and overall process optimization at the IQC step. This also concludes that with the implementation of an automated system improves map availability at the IQC step and significantly enhances overall manufacturing efficiency and product quality. It emphasizes the significance of continuously monitoring and improving processes to maintain ongoing optimization and competitiveness.

1. 0 INTRODUCTION

Optimizing production processes and ensuring product quality are critical factors that directly impact on a company's success. The Incoming Quality Control (IQC) step plays a pivotal role in assessing the quality of incoming materials or components and is essential in preventing defects from entering the production process. Within the IQC step, access to accurate and up-to-date wafer maps that outline product specifications and quality criteria is of utmost importance for efficient and effective inspection.

Value Stream Mapping (VSM) is a lean manufacturing tool that offers a comprehensive approach to analyzing, visualizing, and improving processes. It provides a clear representation of the entire value stream, from the raw materials to the end-product, and highlights opportunities for eliminating waste, streamlining workflows, and enhancing overall productivity. In this context, VSM can be applied to examine the availability of wafer maps at the IQC step, identify bottlenecks, and propose targeted improvements to ensure a seamless and efficient process.

1.1 Background of the Study

Incoming Quality Control (IQC) is a critical function in the manufacturing and production process of materials,

especially in industries dealing with raw materials like STMicroelectronics. The primary functions of IQC, in particular to Wafer Testing, include inspection and verification of Wafer Maps. Alongside the defects, discrepancies and non-conformities on the lot that could affect the product's quality or performance, the availability of map at DIGS server is a vital requirement prior to endorsing an actual lot to the Production line.

An IQC employee follows a set of processes to ensure map availability on the server. The step-by-step process for effectively reflecting the wafer map in the server is shown in Fig. 1.

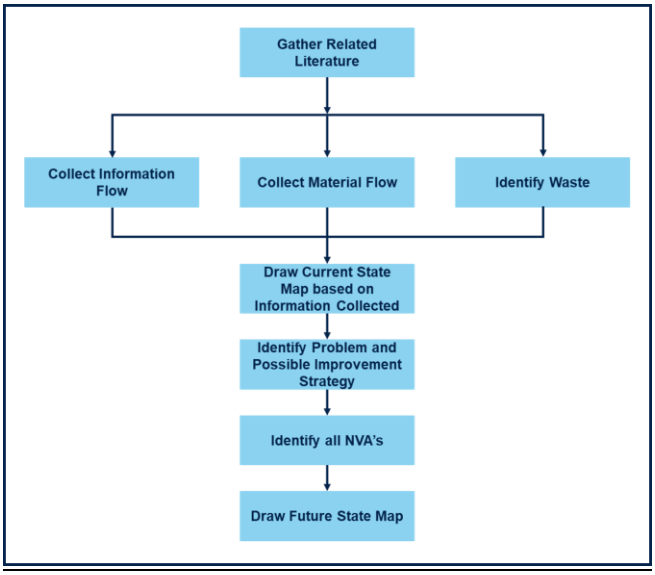

Fig. 1. Checking of Map Availability Current State Process Flow performed both by IQC Personnel and Process Technician

IQC staff will check to see if maps are now available on DIGS Server. If the maps are accessible, IQC staff will ask Process Technician to extract the Fab Ink Map and merge it with the AOI-3 map. The Process Technician will download all maps from the Digs Server and upload them to the Calamba Server. Process Technician will begin map merging after uploading. After all considerations have been made, the Process Technician will notify the IQC Personnel that map merging has been completed. Following that, IQC staff will inspect the yield of Fab Ink Map. Lot can be endorsed to the next step to be loaded in Automated Optical Inspection at Production Line after validation and passing IQC requirements.

1.2 Problem of the Study

The incoming materials, such as wafers, require accurate and up-to-date maps containing critical information about their structure, defects, and specifications to facilitate precise quality inspection and assessment. However, the existing manual handling and management of these maps introduce various issues, including delays, errors, and limited accessibility to essential information. The manual process might involve laborious data entry and non-standardized storage, leading to tailbacks, increased lead times, and potential inaccuracies in quality control. Moreover, the lack of real-time information and centralized data repositories hampers the ability to swiftly respond to quality issues and make informed decisions. The problem necessitates a comprehensive VSM study to analyze the current state, identify improvement opportunities, and explore automation options to streamline the map availability process at the IQC Step.

1.3 Objective of the Study

The goal of this study is to investigate the challenges surrounding map availability at the IQC step and leverage the principles of Value Stream Mapping to create a more streamlined and effective process. By scrutinizing the current state of wafer map accessibility, this research aims to uncover underlying issues that contribute to delays, inefficiencies, and potential quality concerns within the IQC step. Additionally, the study will develop a future state Value Stream Map, showcasing the proposed improvements and anticipated benefits.

1.4 Scope and Limitations

The scope of this study encompasses a comprehensive analysis of the entire map management process from the moment incoming materials, such as wafers, arrive at the facility to their utilization in the IQC Step. The study will delve into the current state of the map availability process, including all relevant personnel.

It will identify constraints and challenges that hinder the smooth and timely availability of maps as a requirement for quality control inspection. Moreover, the research will explore opportunities for process improvement, potential automation solutions, and best practices to optimize the map availability process at the Incoming QC Step.

However, there are certain limitations to be acknowledged. Firstly, the study's focus is specific to the IQC Step and the availability of maps for quality inspection. It does not cover other aspects of quality control or other phases in the manufacturing process. Furthermore, the implementation of automation solutions may not be able to provide detailed cost-benefit analysis or determine the exact return on investment for automation implementation.

2. 0 REVIEW OF RELATED WORK

Value Stream Mapping (VSM) is one of the most effective and widely used lean manufacturing methods for identifying and eliminating waste. FVSM assists in reducing NVAs in a process and making a production flow efficient, productive, and cost-effective [1].

In one project there are two value stream maps. A current state map (CVSM) and a future state map (FVSM). A current state value stream map shows what is the actual process at the beginning of a project. It identifies waste and NVAs. The future state map shows what the process should look like at the end of the project after that improvements are defined and achieved by making changes in the current system. This achieved FVSM will become CVSM for the next project and this cycle continuously runs. VSM is a lean method used to identify opportunities for improvements in the future. VSM method is associated with production as well as with service sectors. It can be used for: Development of new products; Logistics and supply chain activities; Improving productivity hence profitability; Reduction in production and service time; Customer satisfaction; Developing efficient production techniques. Layout/ equipment modification. VSM is an analytical method, and it is based on details, depending on the level of detail, the VSM can address a process step, to one or to the production lines, or to the entire manufacturing industry.

In terms of internal manufacturing, there are three sorts of operations that must be serviced. These are classified as non-value adding, necessary but non-value adding, and value-adding.

Non-Value-Adding activities are completely useless activities that are never used by customers; hence they are referred to as pure waste. These non-value-added activities must be fully eliminated. *Necessary but non-value-added* activities may be regarded as wasteful; however, they are required under the current set of activities. A *value-added* activity entails actions that produce the final product or service through the processing of raw materials and the use of physical labor, but from the perspective of the consumer [2].

Key words: Lean, ***VSM*** *(Value stream map),* ***CVSM*** *(Current state value stream map),* ***FVSM*** *(Future state value stream map),* ***VA*** *(Value added activity),* ***NVA*** *(Non-value-added activity),* **NNVA** *(Necessary non-value-added activity)* [3].

3.0 METHODOLOGY

Prior to using VSM methodology, the research ensures a thorough understanding of the process, encourages collaboration among relevant personnel, and allows the business to make educated decisions to improve quality control and overall production efficiency.

3.1 Research Design

The process analysis is carried out by compiling a list of information from numerous inquiries with specialists at the IQC level, Process Engineers and Technicians, and other associated individuals, as well as directly engaging in time measurement for various processes. The following are the steps in the VSM approach. Collecting Related Literature - Data Collection - Waste Identification - Current State Mapping - Application of VSM Tools - Creating Future State Map as illustrated in Fig. 2

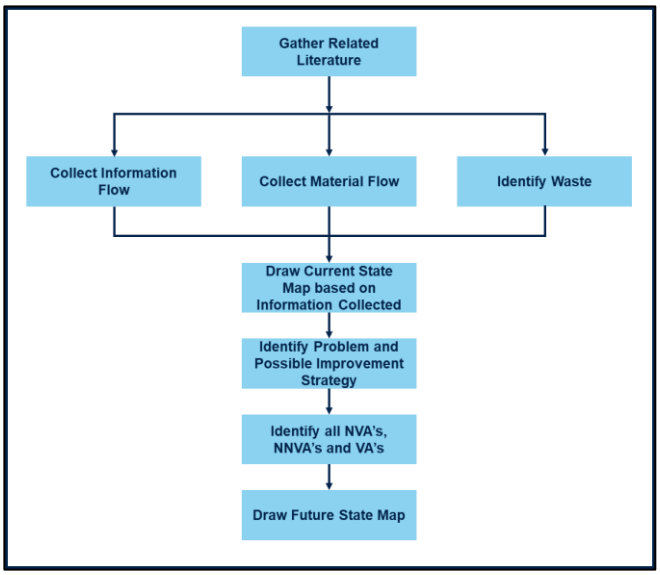

Fig. 2. VSM Methodology applicable in the Wafer Map Availability at IQC step

3.2 Sources of Data Collection

Primary data sources will include the personnel involved in the Incoming Quality Control Step, Process Technician, and other quality control team members. Other Data sources that can be used for this study are relevant documentation, reports and any existing data related to map availability, error logs, control reports and data related to lead times and processing times.

Interviews and Surveys with the identified personnel will also be conducted to gather insights into the map availability process. Questions should focus on the steps involving lead times, challenges faced, and opportunities for improvement.

3.3 Waste Identification

Waste elements contribute to waste and inefficiencies of the map availability process and increased lead times, negatively impacting the overall quality control process [4].

Checking the gathered information during the interview and observation, waiting waste is very evident in the process causing delays in accessing the necessary maps for quality inspection. If the maps are not readily available or if the data entry is longer than necessary, the IQC personnel must wait before proceeding with inspections. This extends lead time and would lead to potential delays in the production process.

3.4 Present Status Evaluation

As illustrated in Fig. 1, one of the requirements for an incoming lot to be advanced to the next step procedure is map availability. Quality control is performed to guarantee that all materials entering the production line have been examined and meet the standards and requirements. This critical aspect of the quality control process ensures that accurate and up-to-date maps are readily available to facilitate precise quality inspection and assessment.

Data input for IQC people and Process Technicians will locate the maps on the server and supply the appropriate information upon receipt of the material. This procedure may need physically retrieving the maps from the server, resulting in longer lead times and associated inefficiencies.

This procedure will take about ~4.5 hours to complete successfully. Data input at the Process Technician's end is equally crucial because it will be done manually. See Table 1.

The entire map availability process was resource-intensive, with valuable personnel time being spent on repetitive manual tasks, leaving limited room for value-added activities and process improvement initiatives.

Micro – Process Responsible	Responsible	Category	Number of minutes to execute completely
Map Availability Check (MP1)	(IQC Personnel)	Necessary activity	30.00
Request for Map Extraction and Merging (MP2)	(IQC-to-Process Technician)	Necessary activity	50.00
Extract Map from Digs Web (MP3)	(Process Technician)	Necessary activity	70.00
Upload Map to Calamba Server (MP4)	(Process Technician)	Necessary activity	117.60
Perform Manual Map Merging (MP5)	(Process Technician)	Necessary activity	220.80
Inform Map Availability (MP6)	(Process Technician to IQC Personnel)	Necessary activity	240.60
Perform Yield Checking of Fab Ink Map (MP7)	(IQC Personnel)	Necessary activity	270.60

Table 1. Current time execution in performing the whole process of Map Availability at the server.

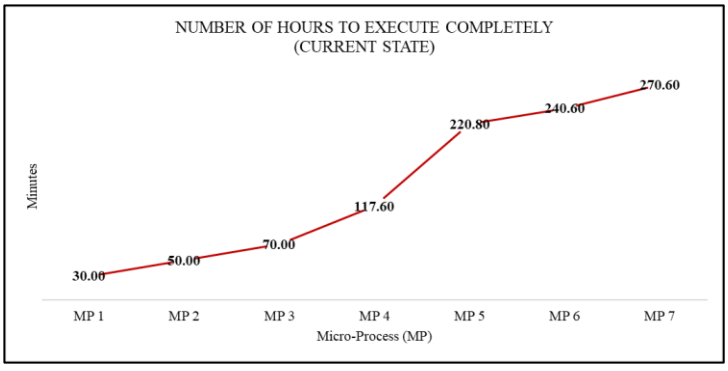

Fig. 3. Current State Time Visualization needed to execute map checking for one lot completely.

3.5 Envisioned Outcome

The use of different lean tools, such as VSM, to optimize the existing flow would ultimately aid in lowering the lead time and enhancing efficiency.

An introduction to automated systems will aid the study in reducing manual efforts and data input mistakes. Fab Ink Map is automatically retrieved from the server, integrated with AOI-3, posted to the server, and placed into the quality control system, removing the need for manual activities between IQC Personnel and Process Technician. This will also lead to real-time accessibility for IQC personnel to maps for immediate quality inspection. The maps are readily available thus enabling prompt and efficient inspections without working times.

4.0 RESULTS AND DISCUSSION

4.1 Current Situation Assessment

The current state mapping of the map availability process at the Incoming Quality Control Step revealed several key findings. Maps are stored in a centralized repository accessible to authorized personnel, but maps require manual retrieval and uploading to Calamba Server, leading to waiting times and potential delays in quality control inspections.

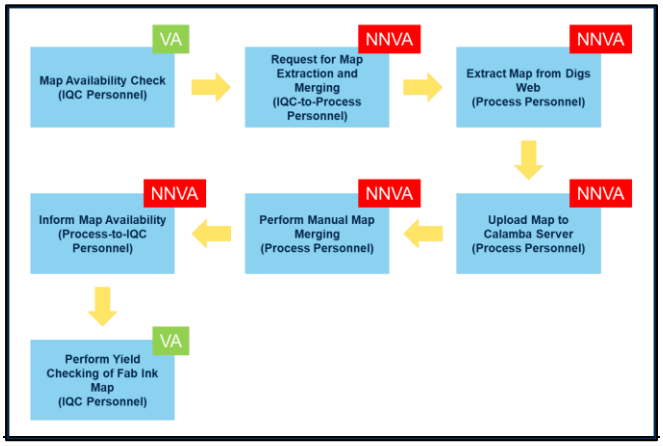

Fig. 4. Checking of Map Availability Future State Process Flow performed solely by IQC Personnel

As shown in Fig. 3, 5 of the 7 processes were identified as non-value-added activities. These are the nice-to-have actions that must be completed in order to meet regulatory criteria or standards. Nonetheless, these actions are essential to ensure specification compliance. Only the combined Fab Ink Map with AOI-3 Map Availability and Yield checks are recognized as must-have value-added activities.

This identified NNVA's are not considered as waste as it still directly adds value to the whole process. Furthermore, these activities may not directly create value from the customer's perspective but are crucial for delivering high process excellence prior movement of lot to next step.

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4.2 Future State Findings

The improved system-based algorithm in the new system will continue to cover all NNVAs. With the automated system, IQC staff will have simple access to verifying maps in the server. This will be a one-time big-time manner without the assistance of Process Technicians. A script is written to integrate AOI-3/OQC maps with Fab-Ink Maps from the fab site. Following the merging, it will be transferred to the Map Warehouse, where IQC workers will be able to assess if the map contains any anomalies discovered at the Fab Site. This might also be the moment at which IQC workers evaluate the lot for movement to the Production Line.

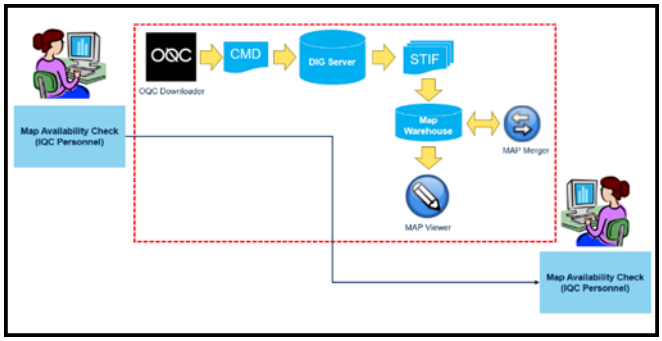

Fig. 5. Visualization of checking for Map Availability at the server performed solely by IQC Personnel

4.3 OQC Map Uploader – the automated system

The entire map availability process was resource-intensive, with valuable employee time being spent on repetitive manual tasks, leaving limited room for value-added activities and process improvement initiatives.

At its core, the system automation relies on a centralized digital map repository where incoming materials' digital maps are securely stored and managed. Upon the arrival of materials, the system instantly receives digital maps directly from suppliers, eliminating the need for manual data entry or physical transportation. This automated data acquisition process ensures real-time availability of maps, enabling quality control personnel to promptly initiate inspections without delays.

As quality control inspections proceed, the system continuously updates inspection results and status in the quality control database. Comprehensive records are maintained, enabling easy traceability and historical analysis for future reference or quality audits.

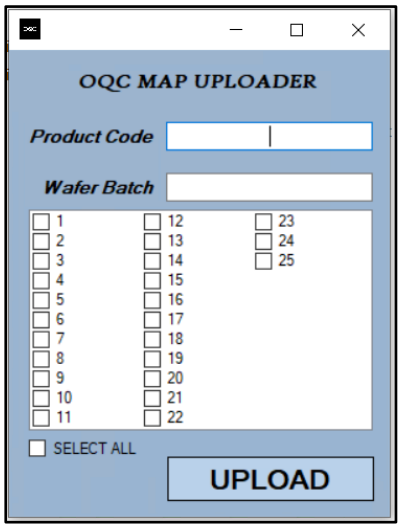

Fig. 6. OQC Map Uploader User-interface. Checking of Map Availability Future State Process Flow performed solely by IQC Personnel

A prompt will pop-up and one minute will take for it to upload in the server and reflect the yield at Map Viewer. By incorporating this efficient data processing and display mechanism, the Map Viewer provides users with real-time insights into the yield of inspected materials, empowering them to make informed decisions for Incoming Quality Control personnel shown in Fig.8

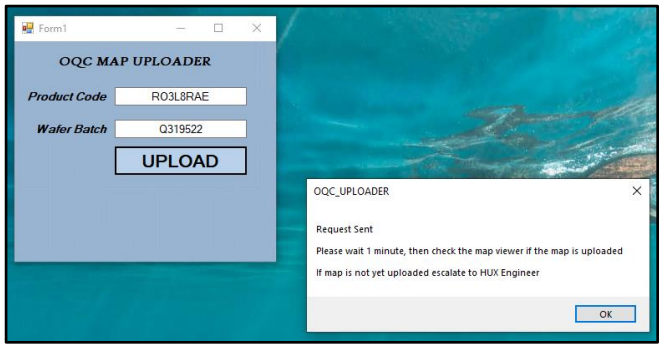

Fig. 7. Actual product code and wafer batch input in the OQC Map Uploader. Indicates a minute will elapse before the maps are completely uploaded to the server.

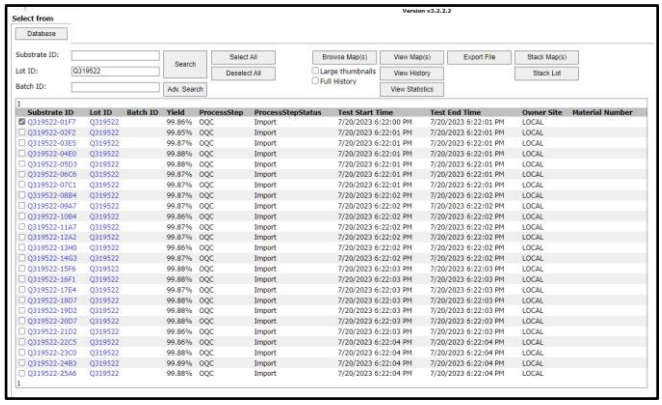

Fig. 8. Map Viewer User-interface. Checking of IQC personnel if the map is available in the server.

In cases where the maps are still not available, a prompt email will be sent to responsible personnel. Employing this automated email prompt system, the organization ensures a proactive approach to handle map unavailability scenarios. The responsible personnel are promptly informed of the issue, enabling them to take immediate action to retrieve the necessary maps, thus minimizing delays in quality control inspections and maintaining efficient operations at the Incoming QC Step.

Fig. 9. Map Viewer User-interface. Checking of IQC personnel if the map is available in the server.

4.3 Percent Improvement

With the implementation of system automation, the time of execution for the map availability process at the Incoming QC Step significantly decreased. Digital maps were automatically retrieved from the centralized repository, eliminating the need for manual transportation, and reducing waiting times.

Micro – Process Responsible	Responsible	Category	Number of minutes to execute completely
Map Availability Check	(IQC Personnel)	Value Added	30 secs.
Request for Map Extraction and Merging	System	Necessary but Non-Value Added	0 hr.
Extract Map from Digs Web	System	Necessary but Non-Value Added	0 hr.
Upload Map to Calamba Server	System	Necessary but Non-Value Added	0 hr.
Perform Manual Map Merging	System	Necessary but Non-Value Added	0 hr.
Inform Map Availability	System	Necessary but Non-Value Added	0 hr.
Perform Yield Checking of Fab Ink Map	(IQC Personnel)	Value Added	30 secs.

Table 2. Time execution after implementation of the system-based checking of Map Availability at the server.

Before the implementation of system automation, the map availability process at the Incoming QC Step relied heavily on manual handling data retrieval, checking, and uploading. Quality control personnel had to physically retrieve maps, manually enter information, and verify data for each incoming material. This manual approach introduced waiting times, delays, and potential errors, especially during data entry.

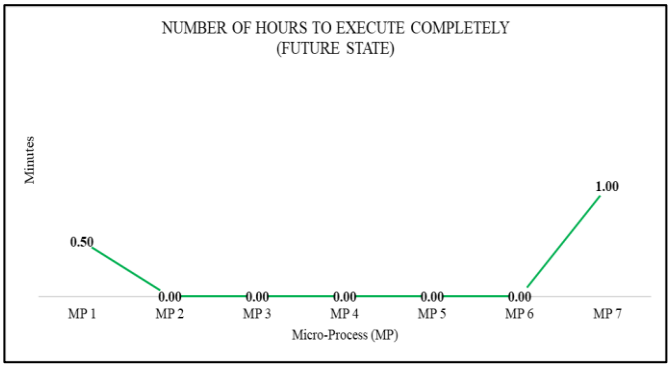

Fig. 10. Future State Time Visualization needed to execute map checking for one lot completely.

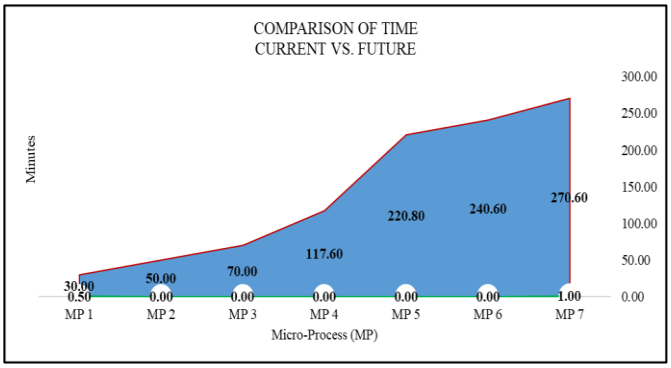

Fig. 11. Future State Time Visualization needed to execute map checking for one lot completely.

Following the introduction of the system automation testing of Map Availability in the server, several significant observations were made, highlighting the positive impact of the automation on the overall quality control process:

1. Improved Efficiency and Speed: One of the most notable observations was the significant improvement in efficiency and speed in the map availability process. With digital maps being automatically retrieved from the centralized repository, the waiting times for quality control inspections were drastically eliminated. Quality control personnel could access the necessary maps in real-time, enabling swift and timely inspections.

2. Enhanced Traceability and Record-Keeping: The automated system improved traceability and record-keeping for quality control inspections. Each inspection result, along with the corresponding map details, was automatically recorded in the quality control database. This comprehensive

data archive enabled easier tracking of product history and supported quality audits and compliance requirements.

3. Enhanced Traceability and Record-Keeping: The automated system improved traceability and record-keeping for quality control inspections. Each inspection result, along with the corresponding map details, was automatically recorded in the quality control database. This comprehensive data archive enabled easier tracking of product history and supported quality audits and compliance requirements.

4. Real-time Monitoring and Reporting: The automated system provided real-time monitoring and reporting capabilities, allowing management to track the status of inspections, identify bottlenecks, and analyze performance metrics. This level of visibility enabled data-driven decision-making and facilitated continuous process improvement efforts.

This successful automation initiative demonstrated the potential of technology-driven improvements in achieving operational excellence and maintaining a competitive edge in the industry.

5.0 CONCLUSION

Through the automation of the system, Value Stream Mapping (VSM) analysis is performed to examine the availability of wafer maps at the Incoming Stage, which has provided significant insights into the current condition of the process. The VSM exercise allowed us to identify bottlenecks and potential for optimization, resulting in shorter cycle times and increased manufacturing efficiency.

It further stated that manual wafer map retrieval and processing caused delays and inaccuracies, lagged deliverables, and extended lead time. It is substantially observed that by adding automation on retrieving Fab Ink Map from the server and finally merging it with the accessible AOI-3 maps, processing time will be reduced, human mistakes will be decreased, and the overall map availability will continue its long-term success.

The automation of the system will not only improve efficiency but also increase accuracy resulting in better decision-making and resource utilization for IQC personnel. The workforce will be empowered to focus more on the value-added task rather than doing repetitive manual processes.

6.0 RECOMMENDATIONS

The researchers would want to propose this study to any future researchers who are doing a Value Stream Mapping (VSM) study. Since system automation is incorporated in this study, future researchers should incorporate predictive analytics throughout the system architecture to improve Incoming Quality Control Personnel decision-making in identifying patterns of defects on the wafer map provided, enabling proactive quality control.

Due to a shortage of time and data, researchers propose analyzing possible hazards connected with this form of system automation, such as system failures, data integrity difficulties, or cyber threats. It would also be welcomed if automation specialists developed techniques to successfully manage these risks and assure the system's reliability.

Benchmarking studies could also be conducted to compare the established system automation and quality control techniques with other top manufacturing organizations and their successful methodologies to encourage future improvements.

7.0 ACKNOWLEDGMENT

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Finally, this study represents the collaborative efforts of numerous people and organizations. The team is extremely appreciative of the organization's and members' contributions to the achievement of this venture.

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Richelle D. Barcarse is a Senior Technician at STMicroelectronics and has a degree in Electronics Technical Course. The study's discussion and recommendations provide more in-depth analysis and comprehension through her valuable knowledge and vast hands-on involvement in the Wafer Test processes.