Jurnal Kejuruteraan 38(5) 2026: 2253-2261
https://doi.org/10.17576/jkukm-2026-38(5)-13

Enhancing Labour Utilization in Semiconductor Manufacturing Through Maynard Operation Sequence Technique (MOST): A Case Study

Wan Hasrulnizzam Wan Mahmood[a*], Mohd Nizam Ab Rahman[b], Abdurrahman Faris Indriya Himawan[c] & Roslan Awang[d]

[a]*Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan, Universiti Teknikal Malaysia Melaka,*

Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[b]*Fakulti Kejuruteraan dan Alam Bina, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia*

[c]*School of Economics and Business, Telkom University, Terusan Buahbatu, Bandung 40257, Indonesia.*

[d]*CADCAM Technology Research Group, Faculty of Innovative Design and Technology, Universiti Sultan Zainalo Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia*

[*]*Corresponding author: hasrulnizzam@utem.edu.my*

Received 16 August 2025, Received in revised form 22 February 2026
Accepted 22 March 2026, Available online 30 August 2026

ABSTRACT

This study investigates the application of the Maynard Operation Sequence Technique (MOST) as a work measurement tool to analyze and improve labour utilization in a high-volume semiconductor manufacturing facility. The research focuses on the End-of-Line (EOL) inspection processes for Quad Flatpack No-Lead (QFN) products, which combine manual and semi-automated operations. Through detailed process mapping, operator activities were observed over full shifts, and sequences were analysed using MOST to establish standard times, assess utilization, and identify inefficiencies. Findings revealed notable variations in task execution among operators, with non-value-added activities such as excessive walking distances, manual documentation, and inconsistent methods contributing to low utilization rates. The average utilization was 13-16% per lot and 41-48% for three lots. The structured steps in the MOST predetermined time study demonstrate that production team members are able to systematically identify the most efficient process steps while eliminating non-value-added activities on the production line. The MOST analysis was able to offer targeted improvement initiatives regarding process standardization, unnecessary motion reduction, layout improvements, and the adoption of systems for digital documentation. These recommendations, if implemented, will also improve the man-to-machine ratio as, optimize workforce deployment, and reduce operating costs without compromising the quality of the product. This also goes on to show that the MOST analysis is effective in measuring time and productivity of the gap analysis in the semiconductor industry and is also relevant to other sectors that are looking for a structured, precise, and pragmatic approach to operational excellence.

Keywords: Maynard Operation Sequence Technique (MOST); work measurement; labour utilization; semiconductor manufacturing; productivity improvement

INTRODUCTION

The Maynard Operation Sequence Technique (MOST) is categorized under predetermined motion time systems and works on the assumption of manual work being carried out as a series of standardized activity sequence blocks. MOST was developed as a more effective counterpart to Methods-Time Measurement (MTM) and classifies work into Basic MOST, Mini MOST, and Maxi MOST, each catering to operations of different duration (Chen et al. 2020). These models explain work in patterns of motion and rest. These patterns include the General Move, Controlled Move, and Tool Use sequences, which integrate sub-activities such as action distance, body motion, object control, and precise placement. The individual breakdown of primitive motions is significantly higher in MTM than in MOST. MOST is more effective in establishing time standards in accuracy and speed for most industrial applications (Chu et al. 2024; Erliana et al. 2025).

Speed of application is the major advantage of the MOST technique. The application of MOST is more efficient than MTM and other detailed PMTS methods. Other studies show that in general manual operations, MOST is applied 5 to 10 times faster than MTM with no substantial loss of accuracy (Chen et al. 2020; Chu et al. 2024). This is why MOST is in real demand in the lean manufacturing discipline. This is because the technique helps in rapid bottleneck analysis, cycle time, and method evaluation alignment with takt time (Rasib et al. 2025). MOST is more rigid giving sequences of motion patterns less variability in analysis interpretation and time data record in the whole set (Karwowski et al. 2025).

The effectiveness and ease of use of MOST has made it common practice for use in line balancing and ongoing process improvement. MOST permits quantitative evaluation of alternative work methods and layouts and tool designs because it is sensitive to method variations. Even minor changes in distance, body motion or handling methods can be incorporated in the calculated standard time for an operation. These data can support continuous improvement activities. This sensitivity of the information enables cost-effective and productivity driven decisions concerning the design of workstations, the flow of work, and the positioning of equipment (Chen et al 2020).

MOST has also become increasingly incorporated into digital human modelling (DHM) and virtual simulation platforms. Chen et al (2020) showed the combination of MOST with DHM made it possible to accurately estimate maintenance time for an operation during the design phase of the product. This permits early assessment of ergonomics and maintainability without the use of physical prototypes, thus lowering development expenses and speeding up revisions to the design. MOST applied in virtual scenarios also allows simultaneous assessment of time and ergonomics, permitting ergonomic design and process engineering changes to be made before they are used. This is very useful in complex fields like aerospace and automotive where maintenance is tedious to perform and the lack of physical access greatly increases the time needed to perform the task.

Unlike traditional applications in production engineering, MOST is becoming increasingly useful in design for disassembly (DfD) and Circular Economy activities. To assess product repairability, De Fazio et al. (2021) used MOST to determine the disassembly times for various components to improve the Disassembly Map method. Their study showed that when MOST was integrated in repairability analysis, design teams were able to recognize various disassembly steps that took the longest time, allowing them to propose redesigns to minimize repair efforts. In context of Circular Economy, Formentini and Ramanujan (2023) used MOST to evaluate disassembly for circular product design and emphasized that time accuracy is crucial in the economic evaluation of component recovery. Their findings on the influence of product end-of-life on disassembly and material recovery were made possible because of MOST's unified framework for assessment.

The value of MOST in managing end of life products has been strengthened in specific sector use cases (Huong et al. 2025). Chu et al. (2024) used MOST to create a smartphone disassembly time estimation model and analyze design scenarios with and without modular battery assemblies. Their findings revealed the potential of design modifications to reduce recycling time and cost. Huang et al. (2025) used MOST in the "Peony diagram modelling" of disassembly of mobile electronics and was able to demonstrate a high degree of correlation between the time estimates from the MOST model and the time actually spent by the technicians. Such validation increases the confidence in time estimates by MOST and reinforces the use of MOST in the design stage to improve rest-of-life management by repair and recycling.

While MOST offers considerable advantages in speed, repeatability, and cross-sector applicability, some limitations must be acknowledged. The higher-level aggregation of activities means that MOST provides less granularity than MTM, which may be necessary for highly repetitive micro-motion tasks or processes where precision in every fraction of a second is critical. Although MOST is easier to learn than MTM, its reliability depends on the correct classification of sub-activities, requiring appropriate analyst training to prevent cumulative errors. Moreover, MOST is most effective for structured, repeatable tasks; its predictive accuracy can diminish in highly variable or unstructured work environments. For critical operations, especially those with safety or cost sensitivity, MOST time estimates should be validated through direct observation and measurement (Chu et al. 2024; Huang et al. 2025).

This paper discusses and examines a case study aimed at establishing the effectiveness of MOST in studying labor utilization in a high-volume electronic manufacturing setting. This is the main concern of the article and serves as the problem statement, as there is a lack of empirical evidence demonstrating the relevance of MOST practices in the industry (Kumar et al. 2020; Belhadj et al. 2025; Singh et al. 2025). The focus of this study is a company that is registered and commenced operations on 14 September 1972 and is considered a pioneer of the electronics industry in Malaysia. The company was purposefully set up to engage in the assembly and testing of semiconductors and has operated this core business for the last 50 years. The company has grown substantially, now employing about 3100 people, and operating a 500,000 square foot manufacturing plant. This has made the company a key player in the industry and a contributor to Malaysia's exports. The company has exported semiconductor products to the United States, Europe, Japan, and the Asia Pacific, amounting to several billion ringgit. This achievement, often described as "Made-in-Malaysia" products, speaks to the international standards of quality that the company is able to deliver on. This in turn demonstrates the company's robust manufacturing prowess.

On top of its monetary profits, the organization has kept its promise of enhancing the technical knowledge and skills of its employees. This investment in world-class manufacturing systems, cutting-edge equipment, and lean operational methodologies has fostered a culture of continuous improvement. This undoubtedly has had a positive impact on the development of manufacturing technologies in the country, including Malaysia, in relation to the country's competitiveness in the global electronics manufacturing supply chain. In this regard, the case study is a perfect opportunity to examine the potential and advantages of MOST as a work measurement and productivity analysis tool in an industrial context. Focused on the effectiveness of MOST, the study aimed to establish how the tool could assist in measuring work utilization, pinpointing productivity drains, and recommending improvements on operational performance. The analysis aimed to integrate the tool into the company's structure as a means to derive necessary steps toward responsible and proactive decisions on resource exploitation, productivity improvement, operational cost reduction, and quality assurance of the systems and components offered by the organization.

This paper is structured as follows. The next section describes the approach used in the research by clarifying the steps taken and the techniques used to gather, handle, and operationally analyze the data. After that, the results from the MOST analysis, along with the discussion that follows, offer interpretations of the pivotal results and their relevance to managerial practices and boosting productivity. The last section of the paper gives the conclusion. It reiterates, with emphasis, the critical points in the research along with the proposals concerning the use of MOST in other comparable manufacturing settings.

RESEARCH METHODS

A case study started in mid-2025 to explore in detail the application and effects of the MOST on the utilization of labour within the chosen manufacturing plant. The research method used was a combination of qualitative approaches and included semi-structured interviews with the top management, focused group discussions with several shop floor leaders, and plant observation in a bid to gather primary data. The semi-structured interviews sought to obtain perspectives both backward concerning the past implementation of MOST, and forward concerning the future plans of the company, including strategic direction, and future operational growth. The centered discussions were aimed at operational leaders with a view to obtaining practical perspectives concerning real-life issues, everyday problems, and bottom-up solutions to the problems.

To add to these qualitative data, real-time dual observation was done on the core elements of the operation of the plant in a bid to obtain captures of actual flows, activities of the operators, together with interactions of people, to ensure the findings were anchored within the real operational context rather than being just reported findings.

Apart from primary sources, secondary data were gathered from internal company documents and some pertinent articles. These secondary sources were most useful in providing contextual background, substantiating primary source data, and placing the company's operating practices in the context of the broader Malaysian electronics manufacturing industry (as Rosdi et al. 2020).

PROJECT DETAILS

To understand and deploy the MOST framework in the evaluation of labour utilisation, it is necessary to understand in detail the process flow of the product in question. This study focuses on the Quad Flatpack No Lead (QFN) package, which is a semiconductor component that is relatively small and thermally efficient and is notorious for being widely used. The QFN assembly process is particularly suited for MOST-based analysis, as it includes a combination of manual and semi-automated operations.

In total, the production system consists of 11 process steps organized in a continuous, product-oriented flow. Special attention is paid to the End-of-Line (EOL) section. The EOL is made up of five processes moulding, deflashing, laser marking, saw singulation, and inspec-tion each of which is necessary to ensure final quality and performance of the product. Understanding these processes and the corresponding operator actions is a first step in applying MOST to these tasks to understand time, motion, and productivity.

QUAD FLATPACK NO LEAD (QFN)

In conducting the MOST analysis, the QFN package was selected because it enables product miniaturization as well as performs demanding electronic functions. Apart from this, QFN leads to better thermal performance as well as reduced inductance and capacitance. It also occupies a smaller package volume and conserves board filing routing compared to traditional leaded SMT packages. This gives it a better fit within fast, compact, and thermally demanding applications. Its lack of leads also improves the QFN's figure of merit by enhancing the manufacturing yield due to lowered handling damage and increased assembly efficiency. QFN in this case study was selected as it requires high precision along with high repetition, making it easier to apply MOST based labor analysis to find productivity improvements beneficial to the company as well as the electronics industry in general. QFN's increasing acceptance in many areas of the industry also reinforces this. Besides, the assembly process of this product provides a good balance of manual and automated tasks that would help find procedure efficiency. This makes QFN a preferred candidate both from a technical aspect and from a strategic aspect as it demonstrates the effectiveness of MOST in analyzing the labor efficiency.

PROCESS FLOW

The production system for QFN products runs on a continuous, product-focused path that achieves both efficiency and uniformity by integrating manual and semi-automated tasks. The complete assembly flow comprises 11 sequential processes, from backgrind to tape and reel. Within the End-of-Line (EOL) section, five key processes are performed: moulding, deflashing, laser marking, saw singulation, and inspection. Inspection is conducted using both automated and manual methods to ensure full compliance with quality standards. This study focuses on the automated inspection area, which uses STI (Scanning Technology Inspection) machines for high-precision quality verification. Figure 1 presents the overall process flow, and the following outlines the specifications for each EOL stage.

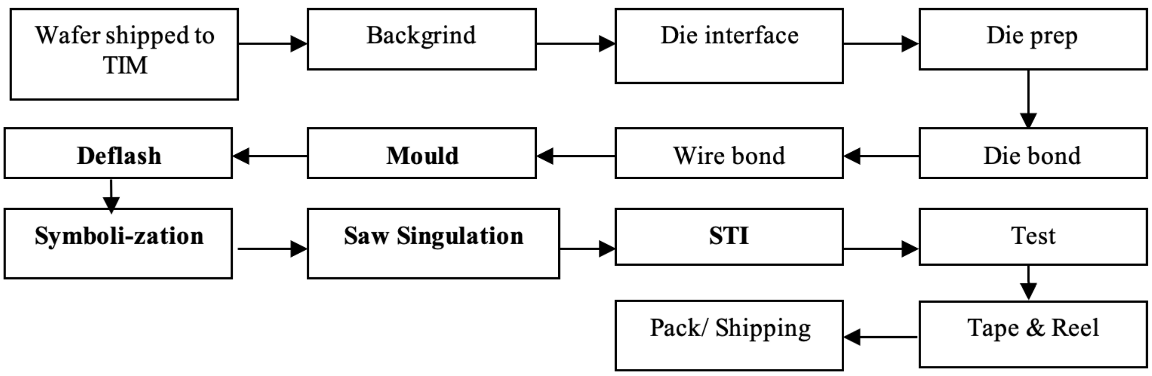

FIGURE 1. Flow chart of assembly process in QFN

The EOL sequence begins with moulding, conducted in a cleanroom using four mould machines with film-assist technology. This step follows die bond and wire bond, and uses three primary materials: mould PET film, mould compound, and mould cleaning material. The PET film prevents resin bleed, lead flash, and spot flash. All machines use a single moulding system with five critical stages, taking around 20 minutes per lot, followed by Post Mold Cure (PMC) baking for about five hours to complete curing and improve structural stability.

After moulding, lots move to deflashing, performed outside the cleanroom using two JetTech machines. The process involves a chemical dip in alkaline Glycol Ethylene (pH 13) to remove resin bleed, film residue, spot flash, and other mould-related defects from leadframes. Deflashing consists of five stages and takes approximately 45 minutes per lot. The next stage, symbolization, uses four laser machines to mark packages in accordance with production traveler specifications. This process is critical for customer-specific orders, such as pachinko lots, which require stricter verification. The laser marks are applied to the package side of the strips to ensure accurate identification and traceability.

Once marked, strips proceed to saw singulation, where 29 saw machines comprising 19 ROKKO, 7 Intercon, and 3 TSK units cut strips into individual units and place them into trays. Intercon machines, the first used in QFN production, operate alongside newer models to maintain throughput. The EOL process concludes with Visual Mechanical (VM) inspection, performed either automatically using 17 STI vision inspection machines or manually at four VM stations. Manual inspection is used for lots without STI-compatible programs. Each shift typically assigns six operators to STI machines and two operators to manual inspection, ensuring all units meet stringent quality and reliability standards prior to shipment.

TABLE 1. Summary of key process from pre-findings

Process Stage	Key Details & Environment	Main Materials / Equipment	Purpose / Function	MOST Application (Work Measurement)
Moulding	Performed in cleanroom; 4 mould machines with film assist; follows die bond & wire bond	PET mould film, mould compound, mould cleaning material	Form package body; prevent defects like resin bleed, lead flash, spot flash	Controlled Move & Tool Use – MOST can measure handling of strips, film loading, machine operation, and curing prep
Post Mold Cure (PMC)	Baking after moulding to ensure curing and strength	PMC oven	Complete curing and improve structural integrity	Controlled Move – Loading/ unloading strips into oven, setting temperature, cycle start
Deflash	Outside cleanroom; 2 JetTech machines; alkaline chemical dip (pH 13)	Glycol Ethylene, JetTech machines	Remove resin bleed, film residue, flash, and mould-related defects	Controlled Move & Manual Work – Material handling, dipping, chemical rinsing, drying
Laser Marking	4 laser machines; marks applied to package side of strips; special verification for certain customers	Laser machines	Apply identification markings; ensure traceability	Controlled Move & Tool Use – Positioning strips, initiating laser cycle, visual verification
Saw Singulation	29 saw machines (19 ROKKO, 7 Intercon, 3 TSK)	Saw machines	Separate strips into individual units; prepare for inspection	Controlled Move & Tool Use – Strip placement, saw operation, handling cut units
Inspection (VM)	17 STI machines (auto) + 4 manual stations; 6 operators for STI, 2 for manual	STI vision inspection machines, VM manual stations	Verify product quality and compliance; manual used if STI program unavailable	Controlled Move & Eye-Hand Coordination – Loading into STI, screen monitoring, rework handling

RESULT AND DISCUSSION

This section presents the findings of the study systematically to ascertain the study's objectives for the initial report. These systematized findings pertain to activity sampling, worker throughput, and other associated productivity metrics.

PERFORMING WORK STUDY ON OPERATOR'S ACTIVITY

The analysis was facilitated through the monitoring of the actions of the operator during the processes using the process mapping technique. Over the period of a twelve hour shift, the observers moved through a systematic description of the process carried out and described the steps within the shift. The process maps that were created were the primary source of the activity guidelines within the Maynard Operation Sequence Technique (MOST) analysis. As with any analysis in MOST, these particulars contributed to the precise calculation of the activity times, and in addition, allowed for other estimates needed to attain the goal of the analysis. For that reason, the accuracy of process maps is important, for the errors in them in one way or another will affect the reliability of the results obtained using MOST. During the observations, it could be seen that although the operators perform the activity, the method or sequence of doing it differs from one another. These variations affect the index in MOST calculation and thus result in different percentages of utilization. Since MOST analysis requires very detailed calculation, process mapping is essential to prevent missing information or sequences in the activities done. The analysis also revealed opportunities for standardizing methods to improve consistency across operators. Aligning all operator methods with a standardized MOST-based sequence could lead to more predictable performance and higher process efficiency.

STANDARD TIME ESTABLISHMENT

The MOST analysis determines the standard time of each activity. Standard time is attained through time allowances. Although each activity is different and varies in the level of difficulties, the defined allowances are the same for the entire process. Regardless of how standard time is configured, defining the most critical processes to what the operators do is crucial. Standard time is critical in deriving the time needed to satisfy a particular demand. In most cases, the assumption would be that the time taken to perform various activities, the time obtained from MOST analysis would be in agreement with the standard time that the analyst has based on the worker's experience in the production line. Equally, the analysis done using MOST provided analysis that is far more objective and easier to quantify than time estimates based on past records. These are the time estimates that are used for standard workload balancing, along with personnel planning, to enhance the accuracy of production schedules.

DETERMINE THE CURRENT OPERATOR'S UTILIZATION

Using MOST analysis, the operator utilization can be obtained. The utilization of operators was initially computed on a per-lot basis, but from the per-lot data, it was converted to an 'at a time' data format. This means that an operator's utilization was measured during the time an operator was engaged in an activity. This indicates that an operator's utilization is not only dependent on the workload level (based on the numbers of lots) but also on the sequence of activities done to achieve every goal. Some activities might be deemed simple but would take a long time to accomplish, in this case, it can be assumed that there is no standard method of accomplishing the task, and thus an operator performs the work in a manner that is comfortable to them. Yet those minor changes in the techniques applied can yield significant variations in a time study. MOST analysis brought to the forefront these variations, thus simple to finding and solving some inefficiencies. With implementation of activity sequences that are more rigid, utilization would be maximized to lower idle time and raise throughput.

An example is as follows;

TABLE 2. Comparison between the time taken to complete same task by different operator

	STI 1 and 2	STI 13 and 14
Activity	Walk 18 steps from machine 1 to the nearest comp and make a report (eg: no material, input problem, output problem) and walk 20 steps to machine	Walk 12 steps from machine 14 to the nearest comp and make a report(eg: no material, input problem, output problem) and walk 12 steps to machine
Activity Sequence	A32 B0 G1 M1 X2 I0 A32	A24 B0 G1 M1 X2 I0 A24
TMU	2720	2080
Time (min)	2.0400	1.560

Table 2 highlights the variation in time required for two different operators STI 1 and 2 versus STI 13 and 14 to perform the same reporting activity within a shift. For STI 1 and 2, the task involves walking 18 steps from Machine 1 to the nearest computer, completing the report (e.g., no material, input problem, or output problem), and then walking 20 steps back to the machine. In contrast, the operator for STI 13 and 14 only needs to walk 12 steps in each direction. This difference in walking distance directly impacts the total time measurement units (TMU) recorded. From a MOST perspective, the "A" index representing the action distance differs between the two cases: 32 TMU for STI 1 and 2 versus 24 TMU for STI 13 and 14. This reduction in TMU is primarily due to the shorter walking distance rather than any change in task complexity. Consequently, the total TMU for STI 1 and 2 is 2,720 TMU (2.04 minutes) compared to 2,080 TMU (1.56 minutes) for STI 13 and 14. The lower TMU for STI 13 and 14 demonstrates how even minor adjustments in travel distance can translate into noticeable time savings when using MOST analysis. However, the root cause of this difference lies in the physical layout of the production floor. The proximity of Machine 14 to the reporting computer inherently reduces travel time for STI 13 and 14, whereas the location of Machine 1 demands longer walking distances. While MOST analysis quantifies this efficiency gap, modifying it would require significant changes to floor area utilization and workflow layout. This finding reinforces the importance of workplace design in reducing non-value-added motion and highlights how MOST can pinpoint improvement opportunities without altering the core task steps.

The activity is to send outlier lots to VM station. The comparison is as follows;

TABLE 3. STI 1 and 2

Outlier Lots (tube)	Activities Sequence	TOTAL TMU	Time (min)
Tie the reject tubes and put it together with traveller on top of box.	A1 B3 G2 A1 B3 P1 A0	110	0.0825
Walk 56 steps to VM station. Bend and put the box at the VM trolley	A0 B0 G0 A96 B6 P1 A0	1100	0.8250
Walk 2 steps to take the production book. Bend and write in the production book to complete details. Walk 56 steps to machine 1	A3 B0 G1 A0 B6 P0 R42 A96	2290	1.7175

Table 3 outlines the sequence of activities for sending outlier lots from STI 1 and STI 2 to the VM station, along with their corresponding MOST (Maynard Operation Sequence Technique) codes, total TMU (Time Measurement Unit), and calculated time in minutes. The process starts with tying the reject tubes and placing them together with the traveller on top of the box, recorded as A1 B3 G2 A1 B3 P1 A0. This task takes 110 TMU, equivalent to 0.0825 minutes, indicating that it is a relatively quick step in the process. Next, the operator walks 56 steps to the VM station, bends, and places the box on the VM trolley. This activity is captured as A0 B0 G0 A96 B6 P1 A0, taking 1,100 TMU or 0.8250 minutes. This step consumes more time due to the considerable walking distance, which is a non-value-added movement but necessary for transporting the outlier lots. Finally, the operator walks two steps to retrieve the production book, bends to write and complete the details, and then walks 56 steps back to Machine 1. The MOST sequence for this is A3 B0 G1 A0 B6 P0 R42 A96, requiring 2,290 TMU or 1.7175 minutes. This final step is the most time-consuming part of the process, mainly due to the combination of walking, bending, and completing manual documentation. Together, these three activities highlight a significant portion of the cycle time being dedicated to manual handling and movement, suggesting potential areas for process improvement through layout redesign, documentation digitisation, or VM station relocation.

TABLE 4. STI 13 and 14

Outlier Lots (tube)	Activities Sequence	TOTAL TMU	Time (min)
Put the rejects on the box and tie it. Walk 10 steps to take the trolley. Walk back 10 steps to machine	A16 B3 G2 A0 B0 P0 A16	220.000	0.165
Take the box and put it on the trolley. Walk 31 steps to VM station.	A1 B3 G1 A96 B3 P1 A0	2160.000	1.620
Bend and put the box on the VM trolley. Walk 2 steps to take the production book. Complete details. Walk 35 steps to MC14	A3 B6 G1 A3 B6 P0 R42 A96	3140.000	2.355

Table 4 presents a MOST time study for the handling process of outlier lots in STI machines 13 and 14. It outlines the sequence of activities, associated MOST motion codes, total TMUs (Time Measurement Units), and equivalent times in minutes. The motion codes (e.g., A16 B3 G2) represent standardised movement categories such as reach, grasp, walk, position, and release allowing each step to be objectively measured. By breaking down activities into elemental motions, MOST provides a precise and consistent basis for calculating standard times. The results highlight notable differences in operator sequences when sending outlier lots to the VM station. For instance, operators of STI 1 and 2 directly carry the box of reject tubes to the VM station, whereas operators of STI 13 and 14 walk an extra 10 steps to retrieve a trolley before proceeding. This variation shows that operators tend to follow their own preferred work methods without realising the impact on standard time and utilisation rates. These differences in approach, though seemingly minor, can accumulate into significant time variations across shifts. Despite the variations, MOST analysis reveals that both operator groups maintain utilisation levels below 50%. This indicates that there is considerable room for improvement in work standardisation and process flow. The utilisation rate, calculated using busy time based on the current output per shift, closely matches the utilisation obtained from the MOST calculation. This alignment suggests that the current performance is consistent with measured standard times, yet optimisation particularly by reducing unnecessary walking and streamlining task sequences could lead to higher productivity and improved standard time attainment. The findings also indicates that manual operations remain the dominant activities on the production line, which encourages the production team to enhance the line by adopting new technologies to improve labour utilisation and optimise manual processes. On the other hands, it has the potential to provide valuable input for activity-based costing, as highlighted by Gananorkar et al. (2019).

CONCLUSION

This study has generated significant findings relevant to productivity improvement in a multinational semiconductor manufacturing company, particularly focusing on the STI 1 and STI 2 outlier lot handling process. Through detailed observation and MOST analysis, the activity sequences of STI inspection machine operators were mapped, revealing that operator tasks vary in sequence and time value. A substantial proportion of the cycle time is consumed by non-value-added activities such as excessive walking and manual documentation, while the average operator utilization per lot remains low at 13–16%, and 41–48% for three lots at a time. These figures indicate that operators are not fully engaged in value-added work, presenting clear opportunities to optimize processes. The MOST analysis proved instrumental in identifying the current utilization rates, pinpointing inefficiencies, and highlighting improvement opportunities such as reducing walking distances, simplifying or eliminating redundant tasks, and introducing digital documentation to streamline processes. These adjustments can help achieve an improved man-to-machine ratio, which in turn leads to a leaner operation with reduced manpower requirements and lower operational costs. Optimizing this ratio not only increases productivity per operator but also allows better allocation of resources across the production line. The application of MOST in this context has demonstrated its effectiveness as a productivity improvement tool, enabling precise measurement of standard times, manpower planning, and operator workload balancing. Beyond the semiconductor sector, the methodology combining systematic observation, detailed time analysis, and process optimization can be applied to other manufacturing industries to drive operational excellence, cost reduction, and sustainable performance gains.

ACKNOWLEDGEMENT

The authors acknowledge and express their sincere appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for providing the necessary funding for this research.

DECLARATION OF COMPETING INTEREST

None.

REFERENCES

Belhadj, I., Ben Abdallah, M. A., Tlija, M. & Aifaoui, N. 2025. A mathematical formulation for assessing disassembly plans based on energy consumption, disassembly time and recyclability for a sustainable design. *International Journal on Interactive Design and Manufacturing (IJIDeM)* 19(10): 6901–6917.

Chen, J., Zhou, D., Kang, L., Ma, L. & Ge, H. 2020. A maintenance time estimation method based on virtual simulation and improved modular arrangement of predetermined time standards. *International Journal of Industrial Ergonomics* 80: 103042.

Chu, X., Li, L., Zhao, F., Sutherland, J. W., Li, F., Li, W. & Song, Y. 2024. Disassembly time estimation for used smartphones based on Maynard operation sequence technology. *Computers & Industrial Engineering* 193: 110291.

De Fazio, F., Bakker, C., Flipsen, B. & Balkenende, R. 2021. The disassembly map: A new method to enhance design for product repairability. *Journal of Cleaner Production* 320: 128552.

Erliana, C. I., Hasanuddin, I., Away, Y., Raja Ghazilla, R. A. & Maisaroh, R. R. 2025. Incorporating time and motion analysis into modular arrangement of predetermined time standard. *Engineering Headway* 21: 43–56.

Formentini, G. & Ramanujan, D. 2023. Design for circular disassembly: Evaluating the impacts of product end-of-life status on circularity through the parent-action-child model. *Journal of Cleaner Production* 405: 137009.

Ganorkar, A. B., Lakhe, R. R. & Agrawal, K. N. 2019. Methodology for application of Maynard operation sequence technique (MOST) for time-driven activity-based costing (TDABC). *International Journal of Productivity and Performance Management* 68(1): 2–25.

Huang, J., Cui, C., Jiang, W., Zhu, L., Li, M., Li, W. & Li, S. 2025. Peony diagram modeling for improving the easy disassembly design of mobile electronic products. *Scientific Reports* 15: 1266.

Huong, N. T., Dao, L. D. & Hanh, L. D. 2025. Achieving operational excellence: Quality improvement in the automation assembly industry. *The International Journal of Advanced Manufacturing Technology* 140(11): 6711–6728.

Karwowski, W., Salvendy, G., Albert, L., Kim, W. C., Denton, B., Dessouky, M., Dolgui, A., Duffy, V., Kumara, S., Li, J. & Madni, A. M. 2025. Grand challenges in industrial and systems engineering. *International Journal of Production Research* 63(4): 1538–1583.

Kumar, R., Kalra, P. & Kant, S. 2020. Productivity enhancement of assembly line by using Maynard operation sequence technique after identification of lean wastages. *International Journal of Productivity and Quality Management* 29(4): 463–482.

Mazareinezhad, F., Sekkay, F. & Imbeau, D. 2025a. Development of a framework to implement time analysis in digital human modeling systems using predetermined motion time systems. *Discover Applied Sciences* 7(5): 1–23.

Mazareinezhad, F., Sekkay, F. & Imbeau, D. 2025b. Field validation of MOST and a DHM-based time estimation method using real-world manufacturing data. *The International Journal of Advanced Manufacturing Technology*: 1–15.

Mazareinezhad, F., Sekkay, F. & Imbeau, D. 2025c. Improving time estimation accuracy in manufacturing systems: Experimental assessment of MOST predetermined motion time system using laboratory data and Fitts' law. *The International Journal of Advanced Manufacturing Technology*: 1–17.

Rasib, A. A., Abdullah, R., Wahyono, F. Z. & Ramli, M. 2025. Enhancing manufacturing efficiency: A case study on automotive assembly line balancing techniques for improving production capacity. *Journal of Engineering Science and Technology* 20(2): 427–441.

Rosdi, M. N. H. M., Mahmood, W. H. W., Kamat, S. R., Tukimin, R. & Ayuni, N. S. 2020. Discovering the classification of manufacturing complexity from Malaysian industry perspective. *Journal of Advanced Manufacturing Technology* 14(2).

Singh, B., Singh, J., Farwaha, H. S., Singh, P. & Ranjan, N. 2025. Implementation of Maynard operation sequence technique in an engine manufacturing industry: A case study. *Journal of The Institution of Engineers (India): Series C* 106(5): 1551–1559.

Ugo-Njoku, C. V. 2023. Time study and motion analysis using Basic Maynard Operation Sequence Technique (MOST) in Pro Time Estimation Software: A case study of the button making process in SIUE MakerLab. *International Journal* 10(4): 2617–2628.

Vinay, R. S., Rajashekar, R. & Ramamurthy, J. 2018. Determination of value added, semi-value added and non-value added activities of an assembly line by Basic Maynard Operations Sequence Technique using ProTime Estimation Software: A case study. *International Journal of Advanced Research Trends in Engineering and Technology* 5(9): 1–6.