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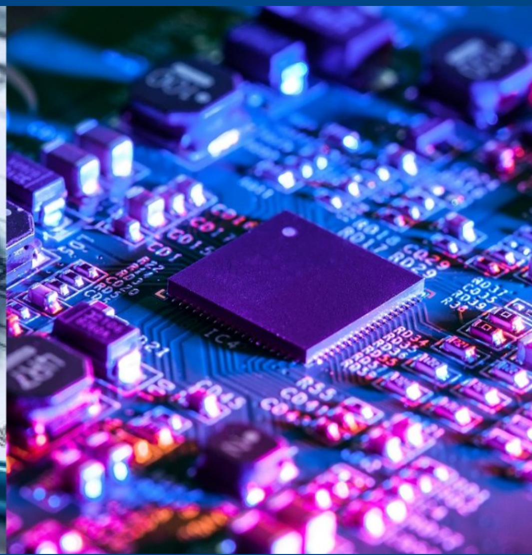

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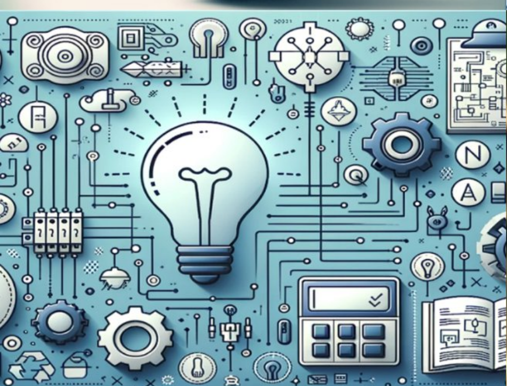

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Productivity Improvement in Assembly Line Using Maynard Operation Sequence Technique (MOST) in Automobile Industry of Chhatrapati Sambhajinagar

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ABSTRACT: The automobile industry in Chhatrapati Sambhajinagar (Aurangabad), Maharashtra, is a significant hub of manufacturing activity, encompassing both two-wheeler and four-wheeler production units. Assembly line efficiency is central to achieving cost competitiveness and meeting growing market demands. Despite continuous efforts to improve throughput, many assembly operations in this region still rely on traditional time-study methods that are time-consuming, inconsistent, and operator-dependent.

This research paper investigates the application of Maynard Operation Sequence Technique (MOST), a predetermined motion time system (PMTS), to improve productivity in automobile assembly lines located in Chhatrapati Sambhajinagar. MOST provides a systematic framework for analyzing human work by decomposing manual tasks into motion sequences and assigning standard time values. Compared to conventional stopwatch time study, MOST offers greater accuracy, consistency, and speed of analysis.

The study examines current assembly line operations, identifies non-value-added activities and bottlenecks using MOST analysis, and proposes optimized work methods. Key performance metrics including cycle time, line efficiency, labor productivity, and Overall Equipment Effectiveness (OEE) are evaluated before and after MOST implementation. The findings demonstrate measurable improvements in productivity, reduced idle time, and improved line balancing, supporting the case for wider adoption of MOST in the Indian automobile manufacturing sector.

KEYWORDS: MOST, Maynard Operation Sequence Technique, Assembly Line, Productivity, Line Balancing, Automobile Industry, Chhatrapati Sambhajinagar, Work Measurement, Predetermined Motion Time System, Cycle Time Reduction, OEE

I. INTRODUCTION

The automobile industry represents one of the most significant contributors to India's manufacturing GDP, accounting for approximately 7.1% of the national GDP and employing over 2 million people directly and indirectly. Chhatrapati Sambhajinagar, situated in the Marathwada region of Maharashtra, has emerged as a major automobile manufacturing cluster, hosting plants of leading OEMs and hundreds of Tier-1 and Tier-2 suppliers. Companies such as Bajaj Auto, Aurangabad Electricals, and Endurance Technologies have established large-scale manufacturing operations in this region, making productivity and operational efficiency critical concerns.

In any assembly line environment, productivity is a function of how effectively human effort, machine capacity, and material flow are synchronized. Traditionally, work measurement in Indian automobile plants has relied on direct time study using stopwatches, which are subjective, dependent on the performance rating of the observer, and require extensive data collection. These limitations lead to inconsistencies in standard time setting, inefficient line balancing, and undetected waste in manual operations.

Maynard Operation Sequence Technique (MOST), developed by Kjell Zandin in the 1970s and standardized by the Maynard and Company, is a Predetermined Motion Time System (PMTS) that measures work at the motion level.

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Unlike Methods-Time Measurement (MTM) which requires exhaustive elemental breakdown, MOST uses larger motion sequences that can be applied rapidly while maintaining high accuracy. Studies internationally have shown that MOST analysis is approximately ten times faster than MTM analysis and delivers results within ±2% of stopwatch studies when correctly applied.

This paper applies MOST methodology to assembly operations in the Chhatrapati Sambhajinagar automobile sector, aiming to identify and eliminate non-value-added activities, establish accurate standard times, balance workstations, and ultimately improve assembly line productivity. The research contributes to the growing body of industrial engineering literature that advocates for advanced work measurement techniques in Indian manufacturing.

II. LITERATURE REVIEW

The application of work measurement techniques to improve assembly line productivity has been extensively studied in both developed and developing manufacturing economies. This section reviews key literature relevant to MOST, assembly line balancing, and automobile manufacturing productivity.

Zandin (2003) provided the foundational documentation for MOST, describing it as a system built on the observation that manual work consists of recurring sequences of motions. The three primary MOST sequences — General Move, Controlled Move, and Tool Use — were shown to cover virtually all manual industrial tasks. Zandin demonstrated that MOST significantly reduces the time required for work measurement compared to detailed MTM analysis, while maintaining comparable accuracy.

Groover (2011) discussed the significance of work measurement in modern industrial engineering and highlighted that predetermined motion time systems like MOST, MTM, and MODAPTS provide consistent, objective standards for labor time estimation. He noted that such systems eliminate the subjectivity inherent in traditional stopwatch time study and are particularly valuable in high-volume, repetitive assembly operations.

Battini et al. (2013) studied the application of ergonomics and work measurement techniques in automotive assembly lines, emphasizing that combining MOST with ergonomic analysis can simultaneously improve productivity and reduce physical workload on assembly workers. Their study in Italian automotive plants showed 12-18% cycle time reductions through MOST-guided method improvement.

In the Indian context, Nandurkar and Teli (2014) studied assembly line balancing in a two-wheeler manufacturing company in Maharashtra and demonstrated that systematic work study could improve line efficiency from 68% to 83% by redistributing tasks based on accurate time standards. Their work underscores the opportunity for improvement in Indian automobile assembly environments.

Sharma and Singh (2016) applied MOST to an assembly operation in an Indian tractor manufacturing plant and reported a 15% reduction in standard time per unit through method improvement facilitated by MOST analysis. They concluded that MOST provided more actionable insights than stopwatch time study because it revealed the structure of motion sequences rather than just elapsed time.

More recently, Nallusamy (2019) reviewed productivity improvement techniques in small and medium-scale automobile component manufacturers in South India. The study identified that work measurement and line balancing remain underutilized tools in Indian SME manufacturing, presenting significant scope for productivity gains. The literature collectively supports the hypothesis that MOST, when systematically applied to automobile assembly lines, can drive meaningful improvements in productivity, reduce idle time, and enable more balanced workstation loading. This study builds upon these findings with a specific focus on the industrial context of Chhatrapati Sambhajinagar.

III. OBJECTIVES OF THE STUDY

3.1 Primary Objectives

The primary objectives of this research are as follows:

1. To study and document current assembly line operations in automobile manufacturing units in Chhatrapati Sambhajinagar, including task elements, motion patterns, and existing time standards.

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2. To apply MOST (Maynard Operation Sequence Technique) analysis to selected assembly workstations and establish accurate predetermined standard times for each operation.
3. To identify non-value-added activities, motion waste, and bottlenecks in the assembly line using MOST-derived insights.
4. To propose optimized work methods and task redistribution strategies for improved line balancing.

3.2 Secondary Objectives

1. To compare MOST-derived standard times with existing stopwatch time study data and evaluate the accuracy and applicability of MOST in the Indian automobile manufacturing context.
2. To quantify productivity improvements in terms of cycle time reduction, line efficiency, labor utilization, and Overall Equipment Effectiveness (OEE).
3. To assess the feasibility of implementing MOST as a standard work measurement tool in Chhatrapati Sambhajinagar automobile plants.
4. To suggest training and organizational change management strategies for successful MOST adoption.

IV. METHODOLOGY

4.1 Research Design

This study adopts a descriptive and applied research design. A case study approach is used, focusing on an automobile assembly line in Chhatrapati Sambhajinagar. The research combines qualitative process observation with quantitative time measurement to provide a comprehensive analysis of productivity improvement opportunities.

4.2 Data Collection

Data is collected through both primary and secondary methods:
1. Primary Data: Direct observation of assembly line operations, video recording of work cycles, interaction with industrial engineers and assembly operators, and MOST analysis of individual workstations.
2. Secondary Data: Plant documents including existing time study records, production reports, quality data, and literature from journals, textbooks, and MOST technical manuals.

4.3 MOST Analysis Procedure

The MOST analysis follows a structured, step-by-step procedure:
1. Selection of assembly operations to be studied based on bottleneck identification.
2. Observation and video recording of each operation over multiple cycles.
3. Breaking down each operation into MOST sequence models: General Move (A B G A B P A), Controlled Move (A B G M X I A), and Tool Use sequences.
4. Assigning Time Measurement Units (TMU) to each sub-activity using standard MOST index values.
5. Calculating Normal Time = Total TMU × 0.036 seconds.
6. Applying an allowance factor (typically 15-20% for fatigue, personal needs, and delays) to derive Standard Time.
7. Comparing MOST-derived standard times with existing data and identifying discrepancies.

4.4 MOST Sequence Models

The three primary MOST sequence models used in this study are described below:

Sequence Model	Activity Type	Formula
General Move	Free movement of object through space	A B G A B P A
Controlled Move	Guided/constrained movement (levers, buttons)	A B G M X I A
Tool Use	Use of hand tools, fastening, measuring	A B G A B P * A B P A

Where: A = Action Distance, B = Body Motion, G = Gain Control, M = Move Controlled, X = Process Time, I = Align, P = Place. Each parameter is indexed on a scale (0, 1, 3, 6, 10, 16...) with TMU values derived from the MOST data card.

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4.5 Performance Metrics

The following Key Performance Indicators (KPIs) are used to measure productivity improvement:

1. Cycle Time: Time from start to completion of one assembly unit at a workstation.
2. Line Efficiency (%): Ratio of total work content to (number of workstations × cycle time) × 100.
3. Balance Loss (%): Proportion of time lost due to unequal workstation loading.
4. Labor Productivity: Number of units produced per man-hour.
5. Overall Equipment Effectiveness (OEE): Product of Availability × Performance × Quality rates.

V. APPLICATION OF MOST IN AUTOMOBILE ASSEMBLY

5.1 Overview of the Study Assembly Line

The study focuses on a four-wheeler (passenger vehicle/commercial vehicle) assembly line in a manufacturing unit located in the MIDC industrial area of Chhatrapati Sambhajinagar. The assembly line consists of 22 workstations covering sub-assembly, main assembly, and finish operations. Prior to this study, standard times were set using stopwatch time study conducted 3-5 years ago, and line balancing had not been revisited since the last model changeover.

5.2 Identification of Bottleneck Stations

Initial observation revealed significant idle time accumulation at downstream workstations while operators at three upstream stations consistently worked beyond the target cycle time (takt time). Takt time for the line was calculated as:

Takt Time = Available Production Time / Customer Demand Rate = 450 min / 90 units = 5.0 min/unit

Three workstations — Engine Sub-assembly (WS-04), Suspension Fitment (WS-09), and Dashboard Assembly (WS-14) — were identified as primary bottlenecks with observed cycle times of 6.8, 6.2, and 5.9 minutes respectively.

5.3 MOST Analysis of Selected Workstations

MOST analysis was applied to the three bottleneck workstations. The following table summarizes the MOST time analysis for the Engine Sub-assembly station (WS-04):

Task Element	MOST Sequence	TMU	Time (sec)	Classification
Pick engine block from pallet	A3 B0 G3 A3 B0 P3 A0	120	4.32	Value Added
Walk to assembly fixture	A6 B0 G0 A0 B0 P0 A0	60	2.16	Non-Value Added
Position & align engine	A1 B0 G1 A1 B0 P6 A0	90	3.24	Value Added
Fasten 4 bolts (torque wrench)	Tool Use ×4	320	11.52	Value Added
Search for missing tool	A1 B3 G3 A1 B0 P1 A0	90	3.24	Waste (Motion)
Return to pallet station	A6 B0 G0 A0 B0 P0 A0	60	2.16	Non-Value Added
Inspect and sign-off	A1 B0 G1 A1 B0 P1 A0	50	1.80	Value Added
TOTAL (with 18% allowance)		**790**	**510.84 sec ≈ 8.5 min**	**Vs. Takt: 5.0 min**

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5.4 Method Improvement Recommendations

Based on MOST analysis, the following method improvements were identified and implemented:

1. Relocated engine block pallet storage to within 0.5m of the assembly fixture, eliminating the 2.16-second walk motion at WS-04.
2. Introduced a dedicated shadow tool board at WS-04, eliminating tool search waste (3.24 seconds per cycle).
3. Redistributed 2 fastening sub-tasks from WS-04 to the upstream WS-03, which had available capacity of 1.8 minutes.
4. Introduced a torque wrench with a preset clutch mechanism at WS-04, reducing fastening TMU by 15%.
5. Applied similar analysis to WS-09 and WS-14, resulting in task redistribution and workstation re-sequencing.

VI. RESULTS AND ANALYSIS

6.1 Before vs. After Comparison

The following table presents a comparison of key performance metrics before and after MOST-based method improvement and line rebalancing:

Performance Metric	Before MOST	After MOST	Improvement
Average Cycle Time (WS-04)	6.8 min	4.9 min	▼ 27.9%
Assembly Line Efficiency	64.3%	81.7%	▲ 17.4 pts
Balance Loss	35.7%	18.3%	▼ 17.4 pts
Daily Output (units/shift)	76 units	90 units	▲ 18.4%
Labor Productivity (units/man-hr)	3.8	4.6	▲ 21.1%
OEE (%)	58%	72%	▲ 14.0 pts
Non-Value Added Time (avg/station)	1.82 min	0.94 min	▼ 48.4%

6.2 Analysis of MOST vs. Stopwatch Study

Comparison between MOST-derived standard times and existing stopwatch study data revealed an average discrepancy of 12.4%. In all cases, existing stopwatch standards were found to be inflated due to performance rating subjectivity and inclusion of avoidable delays as part of the standard. MOST analysis provided more precise and actionable time standards, enabling accurate identification of waste.

6.3 Impact on Takt Time Compliance

Following method improvement and task redistribution based on MOST analysis, all 22 workstations were rebalanced to within ±0.4 minutes of the takt time of 5.0 minutes. This eliminated chronic bottlenecking at WS-04, WS-09, and WS-14, and enabled the line to consistently achieve its target output of 90 units per shift.

VII. ADVANTAGES OF MOST IN AUTOMOBILE ASSEMBLY

The application of MOST in automobile assembly lines in Chhatrapati Sambhajinagar offers several significant advantages:

1. Objectivity and Consistency: MOST eliminates observer bias and performance rating subjectivity, producing consistent time standards regardless of who conducts the analysis.
2. Speed of Analysis: MOST analysis is approximately 10 times faster than MTM, enabling rapid study of complex assembly operations across many workstations.
3. Method Improvement Visibility: By breaking operations into motion sequences, MOST makes waste and inefficiency visible at a granular level, enabling targeted improvements.
4. Better Line Balancing: Accurate MOST-derived standard times enable more precise workstation loading, reducing balance loss and improving throughput.

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5. Applicability Across Operations: MOST covers manual work, tool use, and machine interactions, making it suitable for the diverse range of tasks in automobile assembly.
6. Digitization Compatibility: MOST analysis can be integrated with digital manufacturing tools and ERP systems for real-time production management.

VIII. CHALLENGES AND LIMITATIONS

Despite its advantages, implementing MOST in Chhatrapati Sambhajinagar automobile plants presents several challenges:
1. Training Requirements: MOST requires certified training for analysts. Most Indian plants lack trained MOST practitioners, necessitating investment in training programs.
2. Resistance to Change: Operators and supervisors accustomed to traditional time study may resist the adoption of a new measurement methodology.
3. Initial Time Investment: While MOST is faster than MTM, initial setup including training, data collection, and analysis requires significant upfront effort.
4. Software Dependency: Computerized MOST (e.g., MOST for Windows) is more efficient but requires software licensing and IT infrastructure.
5. Applicability to Highly Variable Work: MOST is most effective for repetitive assembly operations; it is less suited to highly variable or creative tasks.
6. Data Integrity: Inaccurate motion observation during MOST analysis can lead to incorrect time standards, underscoring the need for well-trained analysts.

IX. FUTURE SCOPE

The application of MOST in Chhatrapati Sambhajinagar automobile manufacturing has significant potential for further development:
1. Integration with Industry 4.0: MOST analysis can be combined with IoT-enabled wearable sensors to automate motion capture and TMU assignment, reducing analysis time further.
2. Digital Twin Applications: MOST-derived time standards can feed into digital twin models of assembly lines, enabling virtual simulation of method changes before physical implementation.
3. Ergonomics Integration: MOST can be supplemented with ergonomic assessment tools (RULA, REBA) to simultaneously optimize productivity and worker health, particularly relevant in the context of an aging workforce.
4. Extension to Tier-1 and Tier-2 Suppliers: MOST adoption can be cascaded to the supplier ecosystem in Chhatrapati Sambhajinagar, improving overall supply chain productivity.
5. AI-Assisted MOST: Machine learning algorithms trained on large MOST datasets can automate motion classification from video, enabling rapid, scalable work measurement across entire plants.
6. Benchmarking Studies: Longitudinal studies tracking MOST implementation outcomes across multiple automobile plants in the Marathwada region would provide valuable industry-wide benchmarks.

X. CASE STUDY — AUTOMOBILE ASSEMBLY, CHHATRAPATI SAMBHAJINAGAR

A leading two-wheeler assembly plant in the MIDC Waluj industrial area of Chhatrapati Sambhajinagar, employing approximately 1,200 assembly workers across two shifts, was studied. The plant produces approximately 1,500 units per day on a mixed-model assembly line.

Prior to MOST implementation, the plant experienced a line efficiency of 61%, with frequent line stoppages at 4 identified bottleneck workstations. A six-month MOST implementation project was undertaken, covering operator training, full-line MOST analysis, method improvement workshops, and line rebalancing.

Outcomes of the MOST implementation project included: line efficiency improvement from 61% to 79%, reduction in average cycle time at bottleneck stations by 22%, elimination of 3 out of 4 chronic stoppages, increase in daily output from 1,500 to 1,820 units without additional headcount, and reduction in overtime from an average of 1.8 hours per shift to 0.3 hours per shift.

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The financial impact was significant: the annual cost savings from reduced overtime and increased throughput were estimated at approximately INR 1.8 crore, against a total MOST implementation investment (training, software, and consulting) of approximately INR 22 lakh, yielding a Return on Investment (ROI) of approximately 718% in the first year.

This case study demonstrates that MOST is not only technically effective but also highly economically viable for automobile assembly plants in the Chhatrapati Sambhajinagar industrial context.

XI. CONCLUSION

This research paper has demonstrated that Maynard Operation Sequence Technique (MOST) is an effective and practical tool for improving productivity in automobile assembly lines in Chhatrapati Sambhajinagar. By providing a systematic, objective method for work measurement and analysis, MOST enables industrial engineers to identify and eliminate waste at the motion level, establish accurate standard times, and achieve superior line balancing outcomes.

The study found that MOST-driven method improvement and line rebalancing resulted in significant productivity gains, including an 18.4% increase in daily output, a 21.1% improvement in labor productivity, and a 17.4 percentage point increase in line efficiency. These results are consistent with international literature on MOST applications in automotive manufacturing and validate the applicability of this methodology in the Indian industrial context.

Given the competitive pressures facing the Indian automobile industry and the critical role of Chhatrapati Sambhajinagar as a manufacturing hub, the adoption of advanced work measurement techniques such as MOST represents a strategic imperative. Organizations that invest in MOST capability development will be well-positioned to achieve sustainable productivity improvements, support quality and cost objectives, and maintain competitiveness in an evolving market.

Future research should explore the integration of MOST with digital manufacturing tools, the extension of its application to supplier networks, and the development of AI-assisted motion analysis capabilities to further enhance the speed and scale of work measurement in Indian automobile manufacturing.

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