

WORKFORCE OPTIMIZATION IN AUTOMOTIVE TOOLING: AN ENVIRONMENTAL WORK SAMPLING MODEL

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Article history

Received:
20-04-2026

Accepted:
11-06-2026

Published:
30-06-2026

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Jurnal Teknologi dan
Riset Terapan

Open Access

Abstrak

Penelitian ini mengoptimalkan alokasi tenaga kerja dalam perbaikan cetakan otomotif dengan menggunakan metode *Work Sampling* yang terintegrasi dengan faktor lingkungan, guna mengatasi kelemahan dalam studi waktu konvensional yang sering mengabaikan variabel kontekstual. Data dikumpulkan melalui 210 pengamatan (42 pengamatan per hari selama lima hari) di MWT, Ltd., dengan memperhitungkan faktor lingkungan seperti suhu (31°C) dan getaran (0,5 m/s²). Analisis tersebut mencakup pengujian kecukupan (N'=168,42), pemeriksaan keseragaman, dan perhitungan waktu standar menggunakan faktor penilaian *Westinghouse* sebesar +0,24 dan tunjangan khusus lokasi sebesar 80,5%, yang divalidasi berdasarkan data historis. Hasilnya menunjukkan waktu perbaikan standar sebesar 53,16 menit/*mold* pada produktivitas 90%, yang sekitar 18% lebih tinggi daripada nilai yang dilaporkan dalam studi sebelumnya karena dimasukkannya faktor lingkungan dan kompetensi. Hasil simulasi menunjukkan bahwa penerapan sistem *shift* dua pekerja berpotensi mengurangi risiko penumpukan pekerjaan sebesar 22% dan meningkatkan kinerja waktu tunggu dari 3,2 menjadi 2,6 hari. Faktor lingkungan berkontribusi sebesar 30% terhadap waktu toleransi, mengungkap dampak yang sebelumnya tidak terukur. Studi ini memperkenalkan model hibrida yang mengintegrasikan ergonomi lingkungan ke dalam analisis tugas non-repetitif, menawarkan kerangka kerja praktis untuk meningkatkan produktivitas, alokasi sumber daya, dan efisiensi pemeliharaan di lingkungan manufaktur.

Kata Kunci: Mold Repair, Optimisasi Pekerja, Produktivitas, Standard Time, Work Sampling

Abstract

This study optimizes labor allocation in automotive mold repair using an environmental-integrated Work Sampling method, addressing gaps in conventional time studies that often ignore contextual variables. Data were collected through 210 observations (42 per day over five days) at MWT, Ltd., incorporating environmental factors such as temperature (31°C) and vibration (0.5 m/s²). The analysis included adequacy testing (N'=168.42), uniformity checks, and standard time calculation using a Westinghouse rating factor of +0.24 and a site-specific allowance of 80.5%, validated against historical data. The results indicate a standardized repair time of 53.16 min/mold at 90% productivity, which is approximately 18% higher than values reported in previous studies due to the inclusion of environmental and competency-related factors. Simulation results suggest that implementing a two-worker shift system could potentially reduce backlog risk by 22% and improve lead time performance from 3.2 to 2.6 days. Environmental factors contributed to 30% of allowance time, revealing a previously unquantified impact. This study introduces a hybrid model integrating environmental ergonomics into non-repetitive task analysis, offering a practical framework for improving productivity, resource allocation, and maintenance efficiency in manufacturing environments.

Keywords: Labor Optimization, Mold Repair, Productivity, Standard Time, Work Sampling

1.0 INTRODUCTION

The manufacturing industry, particularly the automotive sector, stands as the backbone of economic growth in developing countries such as Indonesia [1]–[3]. Production efficiency highly depends on a company's ability to manage resources, including labor, machinery, and time. In this context, maintenance departments such as Moldshops play a critical role, as the smooth process of mold repair directly affects the availability of production tools and the accuracy of product delivery [4]–[7]. However, uncertainty in labor allocation is often a hidden bottleneck that can lower productivity and increase operational costs.

Labor allocation issues are related to both quantity and quality. A study by the International Labor Organization shows that inefficient maintenance processes contribute to 34% of downtime in the Southeast Asian manufacturing industry. MWT, Ltd., as a component supplier to AHM and other global automotive companies, faces pressure to meet strict just-in-time production standards [8]. Therefore, optimizing the number of mold repair workers becomes a strategic necessity to minimize bottlenecks and ensure operational sustainability.

Field observations at MWT, Ltd. indicate that the assignment of mold repair labor still relies on empirical experience without a standardized method to measure workload [9], [10]. This lack of standardization results in allocation imbalances, where on certain days one employee handles multiple molds, while on others only one. Such inconsistency triggers backlogs and delays in delivering molds to the production line. Analysis of internal company data further reveals that 15% of mold repair requests in 2023 exceeded the promised lead time, increasing overtime costs by up to 20% and contributing to a 12% rise in sickness absence due to physical fatigue. These conditions highlight the urgent need for a systematic approach to workload measurement and labor allocation [11].

Work Sampling has long been recognized as a fundamental method in productivity analysis, particularly for non-repetitive activities such as mold repair [12], [13]. The method is based on probabilistic principles, where random observations represent the distribution of work activities, enabling the estimation of productive and non-productive time. Previous research by Ramadhani [14] demonstrated the effectiveness of this method in determining standard time with an accuracy rate of 95%, although it was limited to repetitive processes. In addition, the incorporation of allowance factors covering physical, environmental, and psychological aspects through approaches such as the Westinghouse method further refines standard time calculations [15], [16].

Despite its effectiveness, previous studies show several limitations. Research conducted by Kusuma & Firdaus [17] and Tannady [18] demonstrated the application of Work Sampling in engineering and retail contexts, achieving productivity improvements; however, these studies did not consider environmental factors such as temperature, vibration, and ergonomic conditions. Similarly, Pradana & Pulansari [19] reported a reduction in production lead time using Work Sampling but focused

primarily on repetitive assembly activities. Other studies, such as Suroso & Yulvito [20] and Umam [21], highlight that conventional Work Sampling models are less effective for jobs requiring specialized technical competencies and often ignore environmental parameters, potentially leading to underestimation of standard time.

These limitations indicate that existing literature does not provide a comprehensive methodological framework that integrates environmental conditions and technical competence into Work Sampling, particularly for non-repetitive processes such as mold repair. In practice, mold repair involves high technical complexity, reliance on heavy equipment such as hoists, and exposure to challenging environmental conditions (e.g., high temperature, dust, and vibration), all of which significantly influence work performance [22]. Moreover, tool delay time identified in Pradana & Pulansari [19] as a critical factor is often not explicitly measured in conventional approaches.

To address these gaps, this study proposes a modified Work Sampling approach that integrates environmental variables and technical competence into standard time calculation. Unlike previous studies that apply fixed allowance values, this research develops a dynamic allowance model incorporating temperature, vibration, and operator skill levels, thereby providing a more context-specific and accurate estimation of labor requirements. This approach responds to the limitations identified in prior research [12], [15] and extends the applicability of Work Sampling in complex maintenance environments. Therefore, the primary methodological novelty of this study is the integration of environmental ergonomics, tool-delay factors, and operator competency assessment into a single Work Sampling framework for non-repetitive mold repair activities.

Based on the identified gaps, this study aims to: (1) calculate the standard time for mold repair by considering environmental and physical factors using a modified Work Sampling method; (2) determine the optimal number of workers per shift based on actual workload; and (3) formulate recommendations for employee technical competencies based on a skill matrix. Academically, this research contributes to the development of Work Sampling methodology by integrating contextual variables specific to mold repair. Practically, the results provide a scientific basis for improving labor allocation, reducing overtime costs, and enhancing compliance with service level agreements (SLA) in manufacturing operations.

2.0 METHOD

2.1. Research Design

This study uses a quantitative approach based on Work Sampling to analyze productivity and determine optimal labour requirements in the mould repair process. The research design is longitudinal observational, where work activities are systematically observed over a certain period. The selection of this method is based on Work Sampling's ability to capture the variability of non-repetitive activities, such as mould repair, while accommodating specific environmental factors

(vibration, temperature, dust) previously ignored in similar studies [23]. The integration of the rating factor (Westinghouse) and contextual time allowance is the main differentiator from conventional methods, and the practical implications of this study are significant, as it provides a more accurate and applicable approach to determining labour requirements in mould repair processes.

The study was conducted at Plant 3 of MWT, Ltd., North Cikarang, Bekasi, a factory specializing in the production of automotive components made from metal and polymer. The Moldshop environment was chosen as a critical location due to its high-intensity mould repair centre (on average, 15 moulds/month). The environmental characteristics of this location, including exposure to 28-32°C temperatures due to 1300-ton injection moulding machine operations, noise levels of 85 dB, and measured floor vibrations of 0.5 m/s², directly impact work ergonomics and allowance time requirements.

The research sample was meticulously selected to ensure its representativeness and reliability. It included a one-morning shift mould repair operator (07.00-15.00 WIB) with 5 years of work experience, chosen based on task complexity and representation of average workload. The observation objects were eight moulds repaired during five working days, consisting of 4 types: two-plate mould (50%), three-plate mould (30%), and hot runner mould (20%). The moulds were randomly selected from the backlog list to ensure a variety of work complexities (welding, fitting, sandblasting).

The study employed a case-study approach focusing on a representative mold repair operator during a peak production period. The objective was not to establish universally applicable workforce standards, but rather to evaluate labor requirements within the specific operational context of the investigated Moldshop. Therefore, the findings should be interpreted as context-specific and intended to support local operational decision-making rather than broad industrial generalization.

2.2. Work Sampling Procedure

Data were collected through three complementary stages. First, structured observations were conducted using a Work Sampling approach with 42 observation intervals per day at 10-minute intervals, as presented in Table 1. A standardized observation checklist was used to classify activities into two categories: productive activities, which were directly related to mold repair operations, and non-productive activities, which included waiting for tools, personal needs, and other interruptions not directly contributing to the repair process.

Second, documentation analysis was performed using mold repair request forms and maintenance records to verify breakdown types, repair frequencies, and response times. These documents provided supporting information for validating operational data obtained during field observations.

Third, semi-structured interviews were conducted with the Moldshop Manager to confirm operational information, including average repair lead time,

workforce allocation practices, and competency standards applied within the department. Data collection was supported by measurement instruments, including a digital stopwatch with an accuracy of ±0.01 seconds for time recording and a sound level meter for assessing workplace noise conditions.

Table 1: Work Schedule and Observation Intervals for Mold Repair Operators

Working Day	Morning Shift	Break	Day Shift	Observation Interval
Monday-Friday	07.00–12.00 WIB	12.00–13.00 WIB	13.00–15.00 WIB	10 minutes (42 intervals/day)

2.3. Work Sampling Calculation

The Work Sampling method was used to determine productivity levels, standard time, and workforce requirements for mold repair activities. The calculation procedure consisted of four stages: productivity determination, normal time calculation, standard time calculation, and labor requirement estimation.

Productivity (Equation 1) was determined from the proportion of productive observations obtained during random work sampling observations.

$$P = \frac{N_p}{N} \quad (1)$$

Where P is productivity (%), N_p is the number of productive observations, and N is the total number of observations. Normal time was calculated by adjusting the observed cycle time using the Westinghouse rating factor (Equation 2).

$$NT = CT \times RF \quad (2)$$

Where NT is the normal time (minutes), CT is the observed cycle time (minutes), and RF is the rating factor. The rating factor was determined using the Westinghouse System, which evaluates operator performance based on skill, effort, working conditions, and consistency. Standard time was determined by incorporating the allowance factor into the normal time (Equation 3).

$$ST = NT \times (1 + A) \quad (3)$$

Where ST is the standard time (minutes), NT is the normal time (minutes), and A is the allowance factor. The number of laborers was determined based on the relationship between standard time, total demand, and productive working hours (Equation 4).

$$NL = \frac{ST \times TD}{PWH} \quad (4)$$

Where NL is the number of laborers, ST is the standard time (minutes), TD is the total demand, and PWH is the productive working hours (420 minutes/shift).

Data analysis was conducted through several sequential stages. First, a data sufficiency test was performed using a 95% confidence level and 5% accuracy to ensure that the number of observations was statistically adequate. Second, a data uniformity test was carried out by calculating the Upper Control Limit (UCL) and Lower

Control Limit (LCL) to verify the consistency of the observed data. Subsequently, the standard time was determined through three calculation stages, namely cycle time, normal time, and standard time. Finally, the labor requirement was estimated based on the calculated standard time and production demand.

2.4. Allowance Determination

In this study, several operational variables were defined to support the Work Sampling analysis. Productive activities were classified as any direct actions related to mold repair processes, including welding, fitting, sandblasting, assembly, and inspection activities that contributed directly to mold restoration. Non-productive activities referred to activities that did not directly contribute to mold repair, such as tool waiting time exceeding three minutes, unscheduled personal breaks, and environmental disturbances requiring temporary work interruption, including dust evacuation activities.

Allowance time was determined based on eight workplace-related factors, namely physical labor (30%), work attitude (2%), work movement (5%), eyestrain (2%), workplace temperature (20%), atmospheric conditions (10%), environmental vibration (10%), and personal needs (1.5%). These factors were evaluated through direct workplace observation and environmental assessment to reflect the actual working conditions of the Moldshop.

Technical competence was assessed using a skill matrix with a five-level proficiency scale ranging from 1 (basic competency) to 5 (expert competency). The assessment covered nine competency indicators, including welding ability, mold fitting, technical drawing interpretation, measuring instrument utilization, troubleshooting capability, machine operation, quality inspection, safety compliance, and overall mold repair proficiency.

Allowance values were determined based on the allowance factor classification proposed by Niebel and Freivalds [20] and verified through direct workplace observations and environmental measurements conducted in the Moldshop. Each component, including physical workload, posture, movement intensity, temperature exposure, vibration, atmospheric conditions, and personal needs, was assessed according to actual operating conditions. Therefore, the resulting allowance values represent site-specific adjustments rather than generic manufacturing allowances.

Environmental measurements were conducted directly in the Moldshop during the observation period. Workplace temperature was measured using a digital thermohygrometer at three observation points and recorded at hourly intervals. Floor vibration was measured using a vibration meter positioned near the mold repair workstation. Atmospheric conditions were assessed through direct observation of dust exposure generated during repair activities. The collected data were used to determine site-specific allowance factors for standard time calculation.

2.5. Skill Matrix Assessment

The skill matrix (Table 2) used in this study was developed based on the competency standards applied within the Moldshop department. Validation of the competency assessment was conducted through consultation with the Moldshop supervisor and production manager, who possess extensive experience in mold repair operations. Competency levels were evaluated using documented training records, work experience, and operational performance history. The validation process ensured consistency between the assigned competency scores and the actual technical requirements of mold repair activities.

Table 2: Skill Matrix Assessment Criteria

Competency Area	Assessment Basis
Welding Ability	Practical performance and supervisor evaluation
Mold Fitting	Practical performance and repair records
Technical Drawing Interpretation	Competency assessment records
Measuring Instrument Utilization	Practical observation
Mold Assembly	Work performance history
Troubleshooting Ability	Supervisor assessment
Machine Operation	Training records
Quality Inspection	Quality performance records
Safety Compliance	Safety observation and records

The skill matrix used in this study was validated through consultation with the Moldshop supervisor and production manager. Competency levels were evaluated based on documented training records, work experience, and operational performance records. The validation process ensured consistency between competency classifications and actual job requirements.

2.6. Data Analysis

Internal validity was rigorously maintained through a series of measures. These included random sampling of observation time to avoid periodization bias, an inter-rater reliability test with two independent observers, and the calibration of Westinghouse adjustment factors using historical employee performance data. External validation was also conducted by comparing the standardized time results with the company's repair log for the past 3 months, showing an average deviation of 4.2%-lower than the industry tolerance (10%). This study has several limitations that should be considered when interpreting the findings. First, observations were conducted on a single mold repair operator, which may not fully capture variations in work performance across different operators or competency levels. Second, the observation period was limited to five working days and may not reflect seasonal fluctuations, emergency repair conditions, or long-term operational variability. Consequently, the results should be viewed as a case-

specific assessment rather than a basis for direct generalization to all mold repair environments.

Despite the limitations, the results of this study remain practically relevant. Cross-validation with historical data and adaptation of site-specific allowance parameters ensured that the findings are applicable to real-world situations. This emphasis on practical relevance reinforces the need for replication of the study on a wider scale to generalize the findings.

3.0 RESULTS AND DISCUSSION

3.1. Results

This study calculated the standard mold repair time of 53.16 min/mold with an optimal labor requirement of 2 people per shift. The average operator productivity reached 90% (Table 3), with variations in non-productive activities (10%) dominated by hoist waiting time and environmental condition adjustments (Table 4). These findings provide important evidence for improving workforce allocation and maintaining compliance with the company's service level agreement (SLA).

Table 3: Percentage of Daily Productivity

Day	Productive (%)	Non-Productive (%)	Mold Repaired	Dominant Damage Type
1	93	7	2	Pin Hole Welding
2	88	12	1	Sandblasting
3	93	7	2	Slider Fitting
4	90	12	2	Parting Line Repair
5	88	12	1	Sandblasting
Average	90	10	1.6	-

Note:

- Non-productive: Waiting for tools (64%), personal needs (36%).

Source: Direct observation data (June 2024).

Table 4: Work Sampling Observations on the First Day

Number Observations	Time	Activity	Status
1	07.00–07.10 WIB	Morning briefing	Productive
2	07.11–07.20 WIB	Bringing the mold to machine	Productive
14	09.11–09.20 WIB	Apply colorant	Non-Productive
42	14.51–15.00 WIB	Have a chat	Non-Productive

Note: Total productive activity: 39 intervals (93%).

During the five days of observation, eight molds were successfully repaired, consisting of 4 types of damage: pin hole welding (37.5%), sandblasting (25%), slider fitting (25%), and parting line repair (12.5%). The complexity of the work affected the variation in repair time, with parting line repair taking 22% longer than average.

The highest productivity was achieved on Days 1 and 3 (93%), when non-productive activity was only 7%, while Days 2 and 5 showed a decline (88%) due to hoist queuing (Table 3). This pattern indicates a critical dependency on the machine.

The average cycle time (CT) of 23.750 minutes/mold increased to 29.450 minutes after the addition of the rating factor (+0.24) (Table 5). The largest allowance factors came from physical labor (30%) and ambient temperature (20%), which increased the standard time by 80.5%.

Table 5: Westinghouse Rating Factor Adjustment for Mold Repair Operators

Factor	Class	Symbol	Adjustment
Skill	Super Skill	A1	+0.15
Effort	Excellent	B1	+0.13
Condition	Poor	F	-0.07
Consistency	Ideal	A	+0.03

Note:

-Westinghouse method (Niegel & Freivalds, 2003).

-Scores based on operator's historical performance evaluation.

Based on the observed cycle time of 23.75 min/mold and the adjusted normal time of 29.45 min/mold, the standard time was calculated by incorporating the site-specific allowance factor of 80.5%, resulting in a standardized repair time of 53.16 min/mold. This value represents the average repair time under the observed operating conditions and should not be interpreted as the total duration required for all mold maintenance activities.

The environmental measurements have shown that the exposure to a temperature of 31°C, which exceeds the thermal comfort range commonly recommended for industrial work environments, and floor vibration of 0.5 m/s² have contributed to an increase in unplanned rest time by 8 minutes/day, extending the standardized time by 12% compared to theoretical calculations. The skill matrix has revealed a crucial need for improvement. While the operator is optimally skilled in welding (score 4.2/5) and technical drawing interpretation (4.5/5), there is a significant skill gap in injection machine parameter analysis (3.1/5), leading to a 15% additional time for fitting error correction. This finding highlights the importance of competency development programs to improve operational productivity.

The analysis has revealed that 64% of non-productive activities are related to tool delay time (14 minutes/day on average), while 36% are due to personal needs and work posture adjustments. These non-productive activities significantly affect overall process efficiency. Hoist queues occurring at 07.00-08.00 and 14.00-15.00, coinciding with the production shift, further add to the

non-productive time. The resulting standardized time (53.16 min/mold) is 18% higher than Kusuma & Firdaus' study [17] in a similar industry (45 minutes), mainly due to the complexity of automotive moulds and environmental factors that were not measured in the previous study.

The calculated standard time was 53.16 min/mold, obtained from the observed cycle time and adjusted normal time after incorporating the site-specific allowance factor. The value represents the average repair time required for the observed mold repair activities under the studied operating conditions and is consistent with the complexity of welding, fitting, and finishing tasks performed in the Moldshop environment.

The Number of Laborers calculation resulted in 1.013 people/shift, which was rounded to 2 people to accommodate buffer time due to environmental variability. Based on simulation using historical workload data, the proposed workforce allocation was estimated to reduce backlog risk by approximately 22%. These results represent projected operational improvements rather than outcomes from a full-scale implementation.

3.2. Discussion

The 90% productivity level aligns with the Work Sampling principle in Ramadhani [14], but the higher standardized time reflects the need to adapt the method for non-repetitive activities. Here, 'allowance' refers to the additional time allocated to account for environmental factors (temperature, vibration) that may affect productivity. Integrating these factors as part of the allowance addresses the weakness of previous studies that only focused on microergonomic aspects [24].

This result contrasts with Tannady [18], who reported 85% productivity in the retail sector. The technical complexity of mould repair necessitates shorter observation intervals (10 minutes vs. 15 minutes) and makes tool time delays more prevalent (64%) than in other sectors (<50%). This confirms the imperative to modify the Work Sampling model for the heavy manufacturing context, a change that is essential for accurately measuring productivity in such settings.

The contribution of temperature and vibration to allowance time (30%) fills the literature gap identified in the Introduction (Table 6). These findings not only align with the ILO (2022) report [25] on the impact of the work environment on productivity but also provide new, specific, and quantifiable parameters that are unique to mould repair. These findings contribute to the existing literature on environmental factors in productivity measurement.

Table 6: Site-Specific Allowance Determination for Mold Repair Activities

Allowance Factor	Observed Condition	Classification	Allowance (%)
Physical Effort	Manual mold positioning, bolt loosening/tightening using L-wrench, frequent handling of	Heavy Workload	30.0

Allowance Factor	Observed Condition	Classification	Allowance (%)
	heavy molds despite hoist assistance		
Working Posture	Standing position for prolonged periods with occasional squatting during repair activities	Standing/Squatting Posture	2.0
Work Movement	Restricted movement due to limited workspace around repair area	Difficult Movement	5.0
Visual Fatigue	Continuous visual inspection requiring high precision during welding, fitting, and finishing operations	Near-Continuous Visual Concentration	2.0
Workplace Temperature	Ambient temperature ranging from 28–32 °C, with an average of 31 °C during observations	High Temperature Exposure	20.0
Atmospheric Condition	Dust generated during repair and cleaning activities, although non-toxic	Dusty Environment	10.0
Environmental Condition	Floor vibration caused by adjacent 1300-ton injection molding machines (0.5 m/s ²)	Noticeable Vibration Exposure	10.0
Personal Needs	Drinking water, restroom visits, and personal recovery activities	Personal Allowance	1.5
Total Allowance			80.5

The total allowance of 80.5% appears higher than values commonly reported in conventional manufacturing studies. However, the Moldshop environment involves substantial physical handling of molds, prolonged standing postures, elevated ambient temperatures, vibration exposure, and intermittent delays associated with equipment availability. Consequently, the allowance was calculated as a cumulative site-specific adjustment reflecting actual workplace conditions rather than a standard fixed allowance. This approach was adopted to avoid underestimating labor requirements in a non-repetitive maintenance environment.

The unexpected issue of 15% of the moulds requiring rework, attributed to the low machine parameter analysis score (3.1/5), underscores the importance of continuous monitoring and improvement. This issue was not anticipated in the previous study. Skill matrix-based training, which can reduce raw time by 9% based on a simulated increase in competency score to level 4/5, is a potential solution.

The company was advised to add one hoist unit, a move that could significantly reduce delay time and

potentially increase productivity by 7%. Additionally, the use of cooling vests is recommended as a mitigation measure against exposure to high temperatures, potentially reducing physical allowances from 30% to 25%. Other efforts include the development of a real case-based injection machine troubleshooting training module, which aims to improve operator skills in handling technical problems more effectively.

The projected reduction in backlog and lead time was derived from workload simulation using historical production demand and calculated standard time. Since the study did not include a controlled before–after implementation experiment, these results should be interpreted as estimated operational benefits rather than statistically validated performance improvements.

While this study has its limitations, the relevance of the findings for short-term decision-making is a point of confidence. The fact that the five-day duration of the study did not include seasonal disturbances such as power outages or rush orders is a testament to the study's applicability. Cross-validation with historical data showing a deviation of 4.2% further ensures the findings' relevance.

For future research, it is crucial to expand the scope of the study by involving several operators with different levels of competence. This will ensure more accurate and representative results. Additionally, integrating IoT sensors for real-time monitoring of the work environment could provide a more in-depth analysis of external factors affecting productivity. Research can also explore the impact of partial automation implementation, such as robotic welding, in optimizing raw time and improving production efficiency. Academically, this research introduces a work sampling model that integrates environmental variables and technical competence, providing an innovative framework for analyzing non-repetitive maintenance activities. Future implementation studies are required to evaluate the long-term operational impact of the proposed workforce allocation strategy.

Although the calculated labor requirement was based on observations from a single operator, the analysis was intended to support workforce planning within the observed operational setting. The recommendation of two workers per shift reflects the workload characteristics, environmental conditions, and production demands observed during the study period. Therefore, the recommendation should be interpreted as a site-specific operational guideline rather than a universally applicable staffing standard.

4.0 CONCLUSION

This study applied a modified Work Sampling approach to evaluate workforce requirements in mold repair operations at MWT, Ltd. The results showed that productive activities accounted for 90% of the observed working time, indicating a relatively high level of operational productivity. After incorporating the Westinghouse rating factor and site-specific allowance parameters, the calculated standard time was 53.16 min/mold.

Based on the calculated standard time and actual production demand, the estimated labor requirement was 1.013 workers per shift. Considering operational variability and workload fluctuations, the workforce requirement was rounded to two workers per shift to support workload balance and workflow continuity within the observed Moldshop environment.

The competency assessment identified welding ability, technical drawing interpretation, and measuring instrument utilization as critical skills influencing mold repair performance. The integration of technical competency assessment into workforce planning provided additional insight for improving labor allocation decisions in non-repetitive maintenance activities.

Academically, this study contributes to the development of Work Sampling applications by integrating environmental ergonomics, tool-delay considerations, and operator competency assessment into a single framework. The proposed approach provides a more context-specific method for estimating labor requirements in complex mold repair operations.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to MWT, Ltd. for their invaluable support and cooperation in facilitating the case study implementation. Their assistance in providing access to data, resources, and insights has greatly contributed to the depth and quality of this research. This collaboration has been instrumental in advancing our understanding and analysis, and we deeply appreciate their commitment to academic and industrial development.

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