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Analysis of Workforce Workload for Production Efficiency Improvement in Sandal Manufacturing Using Workload Analysis and Cardiovascular Load Methods

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ABSTRACT

This study aims to analyse workforce workload and determine the optimal number of workers in the sandal production process at UD. Al Athyyah Mojokerto using the Workload Analysis (WLA) and Cardiovascular Load (CVL) methods. The company experiences workload imbalances across several production sections, resulting in bottlenecks and the inability to meet production demand. Average monthly demand reaches 5,000 pairs of sandals, whilst actual production only reaches approximately 4,700–4,800 pairs. Data collection was conducted through direct observation, interviews, and stopwatch time studies in the cutting, sewing, assembly, and finishing sections. The collected data were processed to calculate cycle time, standard time, workload percentage, and cardiovascular load values to evaluate both operational and physiological workload conditions. The results show that several workstations are categorised as overloaded, namely Cutting 1 (124%), Sewing 1 (106%), Sewing 2 (117%), Sewing 3 (108%), Sewing 4 (127%), Assembly 3 (102%), and Finishing 2 (105%). Meanwhile, several other activities were classified as underloaded. The CVL analysis indicates that most workers experience moderate to heavy physical workloads, particularly in the sewing and assembly sections, which may lead to worker fatigue and reduced productivity. Based on the analysis results, additional workers are required in overloaded workstations to achieve a more balanced workload distribution and improve production efficiency. The integration of WLA and CVL methods provides a comprehensive evaluation of workforce conditions and supports workforce planning in labour-intensive manufacturing industries.

1. Introduction

Small and medium-sized manufacturing enterprises (SMEs) play a strategic role in supporting the national economy, particularly through job creation and meeting market demand. However, increasing competition requires SMEs to manage their production processes effectively and efficiently. One crucial aspect is human resource management, particularly in determining workloads and workforce numbers that align with production capacity [1]. The manufacturing sector, especially labour-intensive industries, relies heavily on workforce performance to maintain productivity and operational continuity. Human resources are not only responsible for carrying out production activities but also determine the effectiveness of workflow, product quality, and the company's ability to achieve production targets. Consequently, companies must ensure that workforce allocation is balanced and aligned with operational demands to avoid inefficiencies during the production process.

In labour-intensive manufacturing industries, the balance between workload and workforce allocation significantly influences production performance, operational efficiency, and product quality. An inappropriate distribution of workload can result in worker fatigue, bottlenecks, idle time, and reduced productivity. Therefore, companies are required to evaluate workforce utilisation systematically to ensure that each workstation operates under balanced working conditions [2]. An excessive workload can negatively impact workers' physical and mental conditions, leading to decreased concentration, increased error rates, and lower work performance. Conversely, workloads that are too low may result in underutilisation of labour resources and inefficiency in operational costs. Therefore, companies need to maintain an appropriate balance between workload levels and workforce

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capacity in order to support sustainable production performance.

UD Al Athyyah, established in 2010 in Mojokerto, East Java, is an SME specialising in the production of sandals under the Giardo and Atozz brands. The company faces the challenge of an imbalance in workload across production departments (cutting, sewing, assembly, finishing), which impacts productivity. Data shows that average demand reaches 5,000 pairs of sandals per month, whilst actual production stands at only 4,700 pairs, with a backlog of up to 300 pairs. This situation indicates that production capacity is not yet optimal [2]. The inability to fulfil market demand consistently may reduce customer satisfaction and weaken the company's competitiveness in the footwear industry. In labour-intensive manufacturing systems such as sandal production, the smoothness of production flow depends greatly on the synchronisation of activities between workstations. If one production section experiences delays due to excessive workload, the entire production system may be disrupted, resulting in reduced operational efficiency and delayed product delivery.

The imbalance in production activities not only affects output quantity but also has implications for worker performance and operational sustainability. When one workstation experiences excessive workload whilst other sections remain underutilised, production flow becomes disrupted and may increase waiting time between processes. In the long term, these conditions may reduce worker effectiveness, increase physical fatigue, and lower the company's ability to fulfil customer demand consistently [3]. The production process involves 15 workers with the following task distribution: cutting (1 person), upper sewing (5 people), assembly (7 people), and finishing (2 people). A cycle time analysis shows that upper sewing takes the longest (±4.3 minutes/pair), whilst cutting is relatively faster (±2.1minutes/pair). This imbalance has the potential to cause bottlenecks in the production flow [3].

Several previous studies have demonstrated that workload analysis can be effectively used to determine optimal staffing levels and improve production efficiency. Research conducted by Monika and Murnawan [1] showed that Workload Analysis (WLA) was able to identify workload imbalances and support workforce planning in industrial operations. Similarly, Firnanda and Murnawan [3] found that the application of WLA could reduce workload disparities and improve labour utilisation in manufacturing activities. However, studies discussing workload distribution and physical workload simultaneously in sandal manufacturing SMEs are still relatively limited, particularly those integrating Workload Analysis (WLA) and Cardiovascular Load (CVL) approaches. In addition to analysing workload from the perspective of working time, evaluating workers' physical conditions is also important to ensure that the assigned tasks do not exceed workers' physiological capacities. Excessive physical workload can lead to fatigue, decreased concentration, and lower productivity. Therefore, the Cardiovascular Load (CVL) method is utilised in this study to assess workers' physical workload levels based on heart rate measurements during work activities. The combination of WLA and CVL methods is expected to provide a more comprehensive evaluation regarding workforce conditions in the production system [4].

Although previous studies have applied Workload Analysis (WLA) to determine workforce requirements and improve labour utilisation, most of them focus primarily on operational workload based on working time. Meanwhile, studies using Cardiovascular Load (CVL) generally evaluate workers' physiological workload without linking the results to workforce allocation decisions. Consequently, there is limited research that simultaneously examines operational workload and physiological workload in labour-intensive manufacturing SMEs.

Despite the extensive application of Workload Analysis (WLA) in workforce planning studies, previous research has primarily focused on operational workload indicators such as working time, labour utilisation, and staffing requirements. As a result, workforce recommendations are often made without considering workers' physiological capacity and fatigue conditions. Conversely, studies employing Cardiovascular Load (CVL) generally assess physical workload and fatigue levels but rarely translate these findings into workforce allocation and production planning decisions. Consequently, there remains a theoretical and practical gap in understanding how operational workload and physiological workload interact within labour-intensive production systems and how both dimensions can be jointly incorporated into workforce planning decisions.

The scientific contribution of this study lies in the integration of WLA and CVL methods within a single analytical framework. WLA is used to identify workload imbalances and determine workforce requirements, while CVL is employed to assess the physiological impact of workload on workers. By combining these two perspectives, this study provides a more comprehensive evaluation of workforce conditions than studies relying on a single method. The integrated approach enables companies not only to optimise workforce allocation but also to consider worker health and fatigue risks when making workforce planning decisions.

To address this issue, this study employs the Workload Analysis (WLA) method to measure the actual workload and determine the optimal number of staff. This research aims to analyse workload distribution and workers' physical workload in the sandal production process at UD Al Athyyah. Furthermore, this study seeks to determine the optimal number of workers required in each production section in order to improve production efficiency, reduce workload imbalance, and support the achievement of production targets more effectively. The findings of this research are expected to provide practical recommendations for workforce planning in labour-intensive manufacturing SMEs, particularly in the footwear industry.

Unlike previous studies that analyse workload or physical fatigue separately, this research integrates Workload Analysis (WLA) and Cardiovascular Load (CVL) to evaluate both operational and physiological aspects of workforce performance in a sandal manufacturing SME. This integrated evaluation contributes to workforce planning by providing a dual-perspective assessment that supports production efficiency improvement while maintaining worker well-being.

Workload Analysis (WLA) is a widely used method in industrial engineering for evaluating workforce utilisation and determining staffing requirements. The method compares the time required to perform work activities with the available effective working time to identify whether workers are operating under underloaded, balanced, or overloaded conditions. WLA has been extensively applied in manufacturing and service industries to improve workforce planning, reduce inefficiencies, identify bottlenecks, and support productivity improvement initiatives.

Cardiovascular Load (CVL) is an ergonomic assessment method used to evaluate physiological workload based on workers' heart rate responses during work activities. CVL provides an objective measure of physical strain and fatigue by examining the relationship between resting heart rate, working heart rate, and maximum heart rate. The method is widely applied in occupational ergonomics to assess whether work demands exceed workers' physiological capacities and to identify potential fatigue risks that may affect worker performance and health.

Workforce optimisation refers to the process of aligning workforce capacity with operational requirements in order to achieve efficient production performance. Effective workforce optimisation seeks to balance workload distribution, minimise bottlenecks, reduce idle time, and ensure that production targets can be achieved without imposing excessive workload on workers. In labour-intensive manufacturing systems, workforce optimisation plays an important role in improving productivity while maintaining sustainable working conditions.

Ergonomic workload assessment emphasises the evaluation of both operational and physiological aspects of work. From an ergonomic perspective, workload should not be assessed solely based on production output or working time but should also consider workers' physical capabilities and fatigue conditions. Integrating operational workload analysis with physiological workload assessment enables organisations to make workforce planning decisions that support both productivity and worker well-being. Therefore, the combined application of WLA and CVL offers a more comprehensive approach for evaluating workforce conditions and developing sustainable workforce allocation strategies.

2. Research methods

2.1 Research Flowchart

This study began by identifying issues arising in the production process at UD. Al-Athyyah through direct field observations and a review of relevant literature. Subsequently, the research objectives were established to guide the study, namely to determine the required workforce based on the workload. The next stage involved data collection, which included working time data, effective working hours, production cost data, and demand data to support the research. The data obtained was then subjected to uniformity and adequacy tests to ensure it was suitable for use in the research [4].

Once the data was deemed to meet the requirements, it was processed by calculating standard times, which were then used in workload analysis to determine the optimal number of workers. The final stage of this research is to analyse the results obtained, draw conclusions, and provide recommendations related to the research findings [5]. In the research process, a research methodology must be established to address the problem systematically and purposefully. This will also facilitate the analysis of the research. Furthermore, research stages must be defined.

2.2 Problem Identification

The process of identifying the research problem is the initial stage of this study. This study aims to improve our understanding of the current state of the production system, particularly with regard to the use of labor. The main focus of the problem is the number of workers employed and the workload of production staff. Therefore, an analysis is required to determine whether the available workforce is sufficient to meet production requirements [6]. Furthermore, the aim of problem identification is to investigate potential imbalances in the workload of workers at each stage of the production process. When workload levels differ significantly, an imbalance may occur, whereby some workers are overburdened whilst others are not utilized optimally. This situation can lead to inefficiencies and disruptions in the production process [7].

By systematically identifying these issues, it is hoped that a comprehensive picture of workload conditions and workforce distribution can be obtained. This information serves as the basis for determining optimal workforce requirements, enabling the company to align workforce capacity with production targets more efficiently and effectively.

2.3 Field Study

The production processes at the company under study were observed directly during this field study. This stage aimed to gain a better understanding of the prevailing operational conditions, particularly those relating to workers' activities and the production process flow. Through direct observation, the researchers were able to understand the actual working conditions and identify problems [8].

During the field study, the researcher observed how workers carried out their tasks at each stage of production; they noted how tasks were allocated and the time required to complete them. Working environment conditions and established work patterns were also observed to influence employee performance. To ensure that the information gathered was accurate and reflected actual conditions, data collection was conducted systematically [9]. Through this activity, researchers will gain a deeper understanding of the workforce's workload and the elements affecting the efficiency of the production process. Subsequently, the processing and analysis stage relies on the field study data. This enables the research findings to accurately reflect the actual situation and provide appropriate recommendations for the company.

2.4 Research Question

Once the issues have been identified, the next step is to formulate the research problem systematically. The problem is formulated in the form of specific and focused research questions, so as to capture the essence of the issue to be investigated. With a clear problem statement, the research can maintain a precise focus and facilitate the determination of the direction for resolving the problem. The research question also serves as a boundary for the study, ensuring that the discussion does not stray into aspects beyond the defined scope. Through a structured research question, the researcher can identify the type of data required and the appropriate analytical methods to address the existing issues. This is crucial to ensure the research process proceeds effectively and aligns with the objectives to be achieved. Furthermore, the research question serves as the primary guide throughout all stages of the research, from data collection and processing to the analysis and discussion of the research findings. With a clear and focused research question, the research can be conducted systematically, ensuring that the results obtained are more structured, relevant, and capable of providing solutions to the problems under investigation.

2.5 Research Objective

Once the research problem has been clearly identified, the next step is to establish clear and focused research objectives. These objectives are set to ensure that the research proceeds in a systematic manner and that the entire process remains focused on solving the problem that has been formulated. The main objective of this study is to analyse the workload levels of production staff and determine the optimal number of staff using the Workload Analysis (WLA) method.

The primary objective of this research is to analyse the workload levels of production staff and determine the optimal number of staff using the Workload Analysis (WLA) method. This objective also serves as a reference for the analytical steps to be undertaken. The researcher can devise an appropriate research methodology with clear objectives, ranging from data collection and data processing to the analysis of results. This is important to ensure that the research can be conducted systematically and in line with the existing issues. Furthermore, the research aims to provide relevant and practical recommendations for the company. By achieving these objectives, it is hoped that the research findings will provide an overview of the workforce's workload conditions and serve as a benchmark for determining the optimal workforce requirements, thereby enhancing efficiency and achieving production targets more effectively.

2.6 Data Collection Method

The following are the data collection methods used in this study to gather the data required for the research:

2.6.1 Observation

Directly observing the sandal production process is a method of observation used to understand the workflow and the actions carried out by workers at each stage of the process. Observation activities were carried out continuously during production hours to obtain actual operational data. Researchers observed work sequences, production flow, operator activities, machine utilisation, and delays occurring during the production process. The observation results were then recorded systematically to support workload calculations and production analysis.

2.6.2 Work Time Measurement

A stopwatch is used to measure the time taken by workers to complete each production task. This information is used as the basis for conducting a workload analysis. Time measurements were conducted repeatedly for each work activity to obtain representative data. The observed cycle times included cutting, sewing, assembly, and finishing activities. The collected data were later used to calculate average cycle time, normal time, and standard time for each workstation.

2.6.3 Interviews

Interviews were conducted with company representatives to obtain information regarding the production process, the division of labour, and the company's operational conditions. Interviews were also conducted with production workers to gather information regarding work difficulties, fatigue conditions, production targets, and operational obstacles encountered during the production process. The interview results complemented the observational data and provided deeper insights into workforce conditions within the company.

2.7 Data Processing Method

The data is processed once it has met the requirements for adequacy and consistency. This stage is carried out to ensure that the research data is of high quality and reliable. Data processing includes identifying workers' work activities, calculating effective working time, and analyzing the workload experienced by workers at each stage of the production process. Data processing involves identifying workers' tasks, calculating effective working time, and analyzing the workload experienced by workers at each stage of the production process [10]. At this stage, data is processed and analyzed systematically to provide a better picture of the actual workload conditions of the workforce. In addition, the ideal number of workers is calculated based on the available workforce. This process aims to determine how effectively the workforce is utilized in supporting production activities [11].

Once data processing is complete, the workload analysis (WLA) method is used as a basis for analyzing the utilization rate of the workforce's working hours and the alignment between the existing workforce and production requirements. The results of this method can provide accurate information and serve as a basis for decision-making regarding the number of staff required for production.

2.8 Workload Analysis

The next step in this study is to conduct a Workload Analysis (WLA). The Workload Analysis method is used to compare the time required by workers to complete production activities with the available effective working time. The objective of this analysis is to determine the workload level experienced by workers at each stage of the production process and to evaluate whether the existing workforce allocation is appropriate for operational requirements [12]. Through workload analysis, the company can identify the utilisation level of labour at each workstation and determine whether certain sections experience overload or underload conditions. Overload conditions occur when the workload exceeds the worker's normal capacity, whilst underload conditions indicate that workforce capacity is not fully utilised. Identifying these conditions is important to support balanced workforce allocation and improve production efficiency. In this study, workload analysis was conducted systematically through several stages. The first stage involved identifying all production processes and work activities within the company. Direct observation was carried out to determine the sequence of production activities performed by workers in each workstation, including material cutting, upper sewing, assembly, and finishing activities. The results of this stage provided a detailed description of work activities that became the basis for workload calculations.

After identifying work activities, field observations were conducted directly in the production area to understand the workflow and actual working conditions. Researchers observed how workers performed their tasks, production flow between workstations, material movement, and factors affecting the completion time of each activity. This observation also aimed to identify operational obstacles such as waiting time, work delays, and bottlenecks occurring during the production process. The next stage involved conducting a time study using the Stopwatch Time Study method. Time measurements were carried out directly on production workers for each work activity to determine the cycle time required to complete one production cycle. Measurements were repeated several times to obtain representative and reliable data. The collected time data were then processed to calculate average cycle time, normal time, and standard time for each production activity. The processing of observation time data was carried out by recording all measured cycle times and calculating the average working time for each workstation. This average value became the basis for determining normal time and standard time. In calculating standard time, an allowance factor was included to account for worker needs such as rest time, fatigue, personal needs, and unavoidable delays occurring during production activities.

Standard time represents the time required by a worker with normal working ability to complete a task under standard working conditions. The standard time calculation was then used to determine the workload percentage for each production activity. The workload value indicates the extent to which workforce capacity is utilised during the production process. The results of the workload analysis subsequently became the basis for evaluating workforce conditions and determining the optimal number of workers required in each production section.

In addition to workload calculations, this study also considered workers' physical conditions through Cardiovascular Load (CVL) analysis. The integration of WLA and CVL methods is expected to provide a more comprehensive evaluation regarding operational workload and workers' physiological workload, thereby enabling the company to improve productivity whilst maintaining worker performance and health conditions.

2.8.1 *Cardiovascular Load (CVL) Analysis*

The Cardiovascular Load (CVL) method was used to evaluate workers' physiological workload based on heart rate responses during work activities. Heart rate measurements were collected directly from each worker during normal production operations. Three parameters were recorded, namely resting heart rate (HRrest), working heart rate (HRwork), and maximum heart rate (HRmax). The maximum heart rate was estimated using the standard formula of (220 − age) for male workers and (200 − age) for female workers. The percentage of Cardiovascular Load (%CVL) was calculated using the following equation:

$$\%CVL = [(HRwork - HRrest) / (HRmax - HRrest)] \times 100\%$$

The resulting %CVL values were classified according to established workload categories. A value below 30% indicates no significant fatigue, 30–60% indicates that improvements may be required, 60–80% suggests that work should only be performed for short periods, 80–100% requires immediate corrective action, and values above 100% indicate unacceptable working conditions. The CVL method was selected because it provides an objective physiological indicator of worker fatigue and has been widely applied in ergonomic and industrial engineering studies to assess physical workload.

2.9 *Determination of the Optimal Number of Workers*

Based on the results of the workload analysis and data processing carried out, the next step is to calculate the optimal workforce requirements for each workstation. The purpose of this calculation is to determine whether the current workforce is sufficient to handle the existing workload or whether adjustments are still required. The results of this calculation can indicate the need to increase or reduce the workforce so that the production process can run more effectively [13].

The results of the workforce requirement calculation can indicate whether it is necessary to increase or reduce the workforce to ensure the production process runs more effectively. The results can also show how balanced the workload is at each stage of the production process. Businesses can identify work areas with labour shortages or surpluses by understanding these conditions. This forms the basis for assessing the current distribution of the workforce and the allocation of tasks [14].

By determining the optimal workforce size, it is hoped that the company can improve overall work efficiency and productivity. Appropriate adjustments to workforce numbers and distribution can also help the company achieve its set production targets, thereby ensuring that operational performance runs more effectively and sustainably.

3. Results and Discussion

3.1 *Profile of the Research Object Company*

UD. Al Athyyah is a micro, small, and medium-sized enterprise (MSME) operating in the manufacturing sector, specialising in the production of sandals. The company is located in Mojokerto, East Java, and has been operating since

2010. In its business activities, UD. Al Athyyah produces various types of sandals marketed under the Atozz brand to meet local market demand and supply requests from business partners. The production process at UD. Al Athyyah consists of several stages, including material cutting, upper sewing, assembly, finishing, and packaging. The company applies a labour-intensive production system in which most production activities are still carried out manually by workers. Consequently, workforce performance plays a crucial role in determining production continuity, productivity, and the company's ability to achieve production targets.

The company currently employs 15 workers distributed across several production sections. Although the company has experienced business growth and increasing market demand, operational challenges remain, particularly regarding workload imbalance and workforce allocation. Several workstations experience excessive workloads, whilst others remain underutilised. This imbalance affects production flow and contributes to delays in fulfilling customer demand. In addition, the production system implemented by the company is relatively simple, with work activities still relying heavily on workers' physical abilities and manual operations. Continuous and repetitive work activities may increase worker fatigue levels, thereby affecting productivity and work quality. Therefore, further analysis is required to evaluate workload conditions and determine the optimal workforce allocation to improve production efficiency and operational performance.

3.2 Work Activity Data

Data on work activities and the number of workers were obtained through direct observation of the production process at UD. Al Athyyah. The observations were carried out to identify each stage of work performed by the workers and the number of workers involved in each production section. Based on the results of the observations, the production process consists of several main activities, namely cutting materials, sewing the uppers, assembling the sandals, and finishing the products. The number of workers in each section is 1 person in cutting, 5 people in sewing, 7 people in assembly, and 2 people in finishing, bringing the total workforce to 15 people.

Table 2.
Number of Workers

No	Worker Activities	Worker Jobdesk	Total
1	Cutting Material	Cutting	1
2	Sewing Upper	Sewing	5
3	Assembling Sandals	Assembling	7
4	Finishing Product	Finishing	2
	Total Worker		15

Based on Table 2, the assembly section has the highest number of workers, namely seven operators, because this process involves several interconnected work activities. Meanwhile, the cutting section only employs one worker despite having relatively high work demands. This condition indicates a potential imbalance in workload distribution between workstations. The observation results also show that the sewing and assembly sections involve repetitive work activities with relatively high work intensity. These conditions may contribute to worker fatigue and reduced operational efficiency if the workload is not properly balanced. Therefore, workload analysis is necessary to determine whether the current workforce allocation is appropriate for production requirements.

3.3 Work Time Measurement Data

Work time measurement data were obtained through a stopwatch time study conducted directly in the production area. Measurements were carried out for each production activity, namely cutting, sewing, assembly, and finishing. The objective of these measurements was to determine the cycle time required by workers to complete one production cycle for each activity. Data collection was performed repeatedly for 30 observations in each workstation to obtain representative and reliable data. The observed cycle times were recorded in seconds and later used as the basis for calculating average cycle time, normal time, and standard time. These calculations are essential for determining workload levels and evaluating workforce requirements in each production section.

The measurement process also considered actual operational conditions, including worker movements, work pace, material handling, and delays occurring during production activities. This approach was intended to ensure that the collected data accurately reflected the real working conditions in the company. Based on the observation results, several workstations were found to have relatively longer cycle times compared to others. The sewing section, particularly Sewing Worker 2 and Sewing Worker 4, showed higher processing times due to the complexity and precision required in the sewing process. Meanwhile, some assembly activities demonstrated shorter cycle times, indicating relatively lower workloads. The time study results indicate variations in work duration among production activities. These differences affect production flow and may lead to bottlenecks in workstations with longer processing times. Therefore, time measurement analysis is important to identify workload imbalances and support workforce planning decisions.

3.4 Production Data

Production data were obtained from company records, including monthly demand, production output, and unmet production quantities. Based on the collected data, the company receives average monthly demand of approximately 5,000 pairs of sandals. However, actual production output only reaches around 4,700–4,800 pairs per month. The gap between market demand and actual production indicates that the company has not yet achieved optimal production performance. Unmet production targets result in production backlogs, which may negatively affect customer satisfaction and business competitiveness. These conditions suggest that the company's current production capacity is still insufficient to fully accommodate market demand. Several factors contribute to this issue, including workload imbalance, differences in cycle times between workstations, and limitations in workforce allocation. Production activities with high workloads require longer processing times, causing bottlenecks that disrupt production flow continuity. In addition, the labour-intensive production system implemented by the company increases dependence on worker performance and physical capacity. Consequently, inefficiencies in workforce allocation directly affect production output and operational efficiency. Therefore, further workload analysis is required to identify the causes of production delays and determine appropriate workforce adjustments.

3.5 *Company Capacity Data*

Based on the collected data, UD. Al Athyyah has a production capacity of approximately 225 pairs of sandals per day. However, the average daily production output only reaches around 185 pairs. This indicates that the available production capacity has not been fully utilised optimally. The difference between production capacity and actual output reflects inefficiencies occurring during the production process. The reported monthly production output of approximately 4,700–4,800 pairs is derived from the average daily production output of around 185 pairs multiplied by the effective working days in a month. Therefore, the daily and monthly production figures refer to the same production performance data but are presented at different levels of aggregation for analytical purposes. These inefficiencies are associated with workload imbalance, differences in workstation performance, and varying processing times between activities. Workstations with excessive workloads require more time to complete tasks, thereby slowing down overall production flow. The sewing section was identified as one of the critical workstations due to its relatively long processing times and high workload levels [15]. Bottlenecks occurring in this section affect the continuity of downstream activities such as assembly and finishing. As a result, several production stages experience waiting times and idle conditions. The current production conditions indicate that workforce allocation and workload distribution have not yet been optimally balanced. Therefore, it is necessary to evaluate workforce utilisation through WLA and CVL methods to determine the appropriate number of workers required in each production section.

3.6 *Cardiovascular Load Calculation*

Physical workload measurement in this study was carried out using the Cardiovascular Load (CVL) method. The CVL method is used to evaluate workload levels based on workers' physiological responses, represented by a comparison of heart rate during work, heart rate at rest, and maximum heart rate. Where maximum heart rate is (220 – age) for men and (200 – age) for women. The calculated % CVL will then be compared with the established classifications as follows:

1. < 30% = No fatigue
2. 30–<60% = Improvement required
3. 60–<80% = Work for short periods only
4. 80–100% = Immediate action required
5. >100% = Activity not permitted

The workload is calculated using the Cardiovascular Load method as follows:

1. Material Cutting Worker

$$\%\text{CVL} = \frac{120 - 71}{183 - 71} \times 100 = 44\%$$

A CVL value of 44% indicates that the workload falls into the moderate to heavy category, and therefore has the potential to cause fatigue.

2. Sewing Worker 1

$$\%\text{CVL} = \frac{120 - 71}{183 - 71} \times 100 = 44\%$$

A CVL value of 44% indicates that the workload falls into the moderate to heavy category, and therefore has the potential to cause fatigue.

3. Seamstress 2

$$\%\text{CVL} = \frac{110 - 69}{175 - 69} \times 100 = 39\%$$

A CVL value of 39% indicates that the workload falls into the moderate category, meaning the work activities place a significant physical strain.

4. Seamstress 3

$$\%\text{CVL} = \frac{125 - 70}{184 - 70} \times 100 = 48\%$$

A CVL value of 48% indicates that the workload falls into the heavy category, thus posing a high risk of causing fatigue.

5. Seamstress 4

$$\%\text{CVL} = \frac{120 - 71}{184 - 71} \times 100 = 43\%$$

A CVL value of 43% indicates that the workload is moderate to heavy, which is physically demanding.

6. Seamstress 5

$$\%\text{CVL} = \frac{118 - 69}{190 - 69} \times 100 = 40\%$$

A CVL value of 40% indicates a workload in the moderate category, but this still warrants attention as it is quite physically demanding.

7. Assembly Worker 1

$$\%\text{CVL} = \frac{112 - 70}{187 - 70} \times 100 = 36\%$$

A CVL value of 36% falls into the moderate category, indicating that the work involves a considerable physical strain.

8. Assembly Worker 2

$$\%\text{CVL} = \frac{115 - 70}{187 - 70} \times 100 = 38\%$$

A CVL value of 38% indicates a moderate workload, with a level of physical strain that is still tolerable.

9. Assembly Worker 3

$$\%\text{CVL} = \frac{118-72}{187-72} \times 100 = 40\%$$

A CVL value of 40% falls into the moderate category, indicating that the work activity is physically demanding.

10. Assembly Worker 4

$$\%\text{CVL} = \frac{112-72}{190-72} \times 100 = 34\%$$

A CVL value of 34% falls into the moderate category, with a relatively lighter workload compared to other assembly processes.

11. Assembly Worker 5

$$\%\text{CVL} = \frac{118-72}{190-72} \times 100 = 40\%$$

A CVL value of 40% indicates a moderate workload, which requires good work management.

12. Assembly Worker 6

$$\%\text{CVL} = \frac{120-69}{190-69} \times 100 = 42\%$$

A CVL value of 42% indicates a moderate-to-heavy workload, so greater attention needs to be paid to the workers' condition.

13. Assembly Worker 7

$$\%\text{CVL} = \frac{124-72}{188-72} \times 100 = 45\%$$

A CVL value of 45% falls into the heavy category, indicating that work activities are quite strenuous.

14. Finishing Worker 1

$$\%\text{CVL} = \frac{118-71}{188-71} \times 100 = 40\%$$

A CVL value of 40% falls into the moderate category, with a significant workload.

15. Finishing Worker 2

$$\%\text{CVL} = \frac{116-70}{188-70} \times 100 = 39\%$$

A CVL value of 40% also falls into the moderate category, with a workload level that is relatively similar to that of Finishing Worker 1.

Based on the results of an analysis using the Cardiovascular Load (CVL) method, the majority of workers fall into the moderate to heavy workload category. High CVL values were found primarily in the sewing and assembly departments, indicating that activities in these departments place considerable physical demands on workers.

This situation indicates a potential for worker fatigue, which could lead to reduced productivity and a decline in work quality. Therefore, better workload management is required through adjustments to staffing levels and improvements to working methods.

3.7 Calculation of Average Cycle Time

The average cycle time was calculated to determine the time required to complete one work cycle for each production activity, based on data from 30 observations. The calculation was performed by summing the total observation times for each activity and then dividing this by the number of observations, thereby obtaining an average value used as the basis for calculating standard time and target time [16]. The following are the average calculations for each worker's activity using the existing formula:

1. Cutting Worker

$$\bar{x}\frac{\sum xi}{n} = \frac{3610.14}{30} = 120.34$$

Cutting 1 has an average cycle time of 120.34 seconds.

2. Sewing Worker 1

$$\bar{x}\frac{\sum xi}{n} = \frac{2939{,}72}{30} = 97{,}99$$

Sewing 1 has an average cycle time of 97.99 seconds.

3. Sewing Worker 2

$$\bar{x}\frac{\sum xi}{n} = \frac{3386{,}75}{30} = 112{,}89$$

Sewing 2 has an average cycle time of 112.89 seconds.

4. Sewing Worker 3

$$\bar{x}\frac{\sum xi}{n} = \frac{3150{,}81}{30} = 105{,}03$$

Sewing 3 has an average cycle time of 105.03 seconds.

5. Seamstress 4

$$\bar{x}\frac{\sum xi}{n} = \frac{3558{,}00}{30} = 118{,}60$$

Seamstress 4 has an average cycle time of 118.60 seconds.

6. Seamstress 5

$$\bar{x}\frac{\sum xi}{n} = \frac{1543{,}42}{30} = 51{,}45$$

Sewing 5 has an average cycle time of 51.45 seconds.

7. Assembly Worker 1

$$\bar{x}\frac{\sum xi}{n} = \frac{2573,47}{30} = 85,78$$

Assembly Worker 1 has an average cycle time of 85.78 seconds.

8. Assembly Worker 2

$$\bar{x}\frac{\sum xi}{n} = \frac{2405,02}{30} = 80,17$$

Assembly Worker 2 has an average cycle time of 80.17 seconds.

9. Workers in Assembly 3

$$\bar{x}\frac{\sum xi}{n} = \frac{2857,79}{30} = 95,26$$

Assembly 3 has an average cycle time of 95,25 seconds

10. Assembly 4 Worker

$$\bar{x}\frac{\sum xi}{n} = \frac{2719,39}{30} = 90,65$$

Assembly 4 has an average cycle time of 90.65 seconds.

11. Assembly 5 Worker

$$\bar{x}\frac{\sum xi}{n} = \frac{2180,31}{30} = 72,68$$

Assembly 5 has an average cycle time of 72.68 seconds.

12. Assembly Worker 6

$$\bar{x}\frac{\sum xi}{n} = \frac{2249,82}{30} = 74,99$$

Assembly 6 has an average cycle time of 74.99 seconds.

13. Assembly 7 Workers

$$\bar{x}\frac{\sum xi}{n} = \frac{1891,02}{30} = 63,03$$

Assembly 7 has an average cycle time of 63.03 seconds.

14. Finishing Worker 1

$$\bar{x}\frac{\sum xi}{n} = \frac{2687,79}{30} = 89,59$$

Finishing 1 has an average cycle time of 89.59 seconds.

15. Finishing Worker 2

$$\bar{x}\frac{\sum xi}{n} = \frac{3060}{30} = 102,02$$

Finishing 2 has an average cycle time of 102.02 seconds.

Based on the results of the average cycle time calculations, it is evident that there is variation in work duration between activities, with some activities having relatively longer times compared to others, whilst others are shorter. This indicates an imbalance in the workload within the production system, necessitating an evaluation to improve efficiency and maintain the smooth flow of the work process. Furthermore, these differences in cycle times can also affect the production flow and potentially lead to a backlog of work in certain activities. Therefore, efforts to balance the workload are required, such as improving working methods, reorganising task distribution, or adjusting the number of workers so that the production process can run more optimally and stably.

3.8 Workload Calculation

Once the standard output values for each production activity have been obtained, the next step is to calculate the workload for each production process. Workload analysis is carried out to determine the level of workforce capacity utilisation in achieving the predetermined production targets [17]. From these calculations, the workload status for each production activity can be determined—whether it is underloaded, normal, or overloaded. The results of this analysis are then used as the basis for determining the appropriate workforce requirements for each production process. Below are the results of the workload calculations for each worker activity.

Based on the workload calculations for each production activity, it is evident that several processes are in an overload condition as they have workload values exceeding 100%, namely in the Cutting 1, Sewing 1, Sewing 2, Sewing 3, Sewing 4, Assembly 3, and Finishing 2 processes. These figures indicate that the workload in the relevant processes is high, which could affect workforce efficiency if this situation persists. On the other hand, several processes such as Sewing 5, Assembly 1, Assembly 2, Assembly 4, Assembly 5, Assembly 6, Assembly 7, and Finishing 1 have workload values below 100%, meaning they are underloaded. This situation indicates that the utilisation of labour capacity in some activities is still suboptimal. In general, the results of the analysis.

3.9 Analysis of Cardiovascular Load Results

Based on the results of the Cardiovascular Load (CVL) calculations, it was found that the level of physical workload for workers in the Atozz sandal production department falls within the moderate to high category. The CVL value indicates the level of physical fatigue experienced by workers based on a comparison of their working heart rate with their maximum heart rate during production activities [17], [18]. The higher the CVL value, the greater the physical strain on the workers.

The CVL results were consistent with field observations and interview findings. Workers in the sewing and assembly sections reported higher levels of physical fatigue due to repetitive motions, prolonged sitting or standing postures, and continuous production demands. These observations support the CVL measurements, indicating that the physiological workload assessment accurately reflects actual working conditions within the production system.

The analysis results show that several production activities, particularly in the sewing, assembly, and finishing sections, have relatively high CVL values. These conditions are influenced by work activities that are performed repeatedly and continuously, as well as the high production targets that workers must meet. High CVL values indicate a potential for work-related fatigue that can affect concentration, work speed, and the quality of production output if sustained over a long period. From an ergonomic perspective, the high CVL values observed in the sewing and assembly sections can be associated with repetitive work motions, prolonged static postures, and continuous production activities with limited recovery periods [17]. These conditions increase physiological strain and may contribute to the development of work-related musculoskeletal disorders (WMSDs), reduced concentration, and higher fatigue levels. If sustained over long periods, excessive physical workload may negatively affect worker well-being, job satisfaction, and long-term productivity. Therefore, ergonomic improvements such as work rotation, scheduled rest breaks, and workstation redesign should be considered to reduce physical strain and support worker health. When linked to the results of the WLA, activities with a high workload tend to show higher CVL values. This indicates that a high workload contributes to increased physical strain on workers. Therefore, adjustments to workforce numbers and a more balanced division of labour are required to reduce worker fatigue levels and improve work productivity.

3.10 Analysis of Workload Analysis Results

Based on calculations using the Workload Analysis (WLA) method, it has been found that the workload in the Atozz sandal production process at UD Al Athyyah is not evenly distributed. This is evident from several production activities having a WLA value of more than 1, indicating that the workload in these processes has exceeded the workforce's normal working capacity. This situation indicates an overload that has the potential to cause work-related fatigue and affect the effectiveness and quality of the production output. The activities experiencing an overload include Cutting 1, Sewing 1, Sewing 2, Sewing 3, Sewing 4, Assembly 3, and Finishing 2. The high WLA values in the sewing sections are influenced by work processes requiring high precision and relatively longer processing times. Meanwhile, in the assembly and finishing sections, the high workload is caused by activities carried out continuously with substantial production targets. On the other hand, some production activities have WLA values of less than or close to 1, meaning that workforce capacity in those sections is still able to meet work demands. This situation indicates an imbalance in workload between workstations, which can result in sub-optimal production. The imbalance in workload distribution also affects the continuity of the production flow. Workstations experiencing overload conditions tend to become bottlenecks because the processing time required is longer than that of other sections. As a result, downstream workstations may experience delays or waiting time due to the accumulation of semi-finished products in overloaded sections. This condition reduces overall production efficiency and contributes to the company's inability to fully meet market demand. The sewing section was identified as the most critical production area because several sewing operators recorded WLA values exceeding 100%. Among all sewing activities, Sewing 4 recorded the highest workload level (127%). This condition is associated with its relatively long average cycle time of 118.60 seconds compared with other sewing activities. The longer processing time indicates that Sewing 4 involves more time-consuming operations and requires greater precision during task execution.

As a result, the operator is required to sustain a higher work intensity to meet production targets, leading to a significantly higher workload percentage. This finding suggests that the overload condition is not solely caused by workforce shortages but also by differences in task complexity and processing requirements among sewing activities. This indicates that workers in this section are required to work beyond normal capacity to achieve production targets. The sewing process involves repetitive manual movements and requires high concentration and precision, which increase both physical and mental workload levels. If these conditions continue over a long period, worker fatigue may increase and potentially reduce product quality consistency. In addition, the overload condition identified in the cutting and finishing sections indicates that the number of workers allocated to these activities is still insufficient compared to the existing workload. The cutting section, which only employs one worker, has a relatively high workload due to continuous production demands. Similarly, the finishing section experiences high work intensity because it serves as the final stage before products are distributed. Consequently, delays occurring in this section directly affect product completion and shipment schedules. Meanwhile, several assembly activities and Sewing 5 were categorised as underloaded because their workload values remained below 100%. This condition indicates that workforce capacity in these sections is not fully utilised. The existence of underloaded workstations suggests opportunities for workload redistribution or workforce reallocation to achieve more balanced operational conditions. By redistributing tasks appropriately, the company may reduce overload conditions in critical workstations without significantly increasing labour costs.

From an operational perspective, overload conditions in the sewing section create production bottlenecks that restrict the flow of materials to downstream processes. Because sewing activities require longer processing times and higher precision, delays occurring in this section directly affect assembly and finishing operations. As a result, work-in-process inventory accumulates between workstations, increasing waiting time and reducing overall production efficiency. This finding explains why the company is unable to fully achieve its monthly production target despite having sufficient nominal production capacity.

The results of the Workload Analysis are also consistent with the Cardiovascular Load (CVL) analysis results. Workers with high WLA values generally demonstrated higher CVL percentages, indicating that excessive operational workload contributes directly to increased physical strain. This relationship confirms that workload imbalance not only affects operational performance but also impacts workers' physiological conditions and fatigue levels. Therefore, workforce adjustments are necessary not only to improve productivity but also to support worker health and occupational safety.

The observed relationship between WLA and CVL results suggests that operational workload and physiological workload are closely interconnected within the production system. Workstations with excessive workload levels require workers to maintain higher work intensity, perform repetitive movements more frequently, and sustain concentration for longer periods. These conditions increase energy expenditure and cardiovascular responses, which are reflected in higher CVL values. In contrast, workstations with lower workload levels generally impose less physical strain on workers. This finding indicates that workload imbalance should not be viewed solely as an operational issue but also as an ergonomic concern that may affect worker health, fatigue, and long-term productivity. Therefore, workforce allocation decisions should consider both workload efficiency and physiological capacity to achieve sustainable production performance.

The findings of this study are consistent with previous studies conducted by Firnanda and Murnawan [3], which reported that workload imbalances can lead to inefficient workforce utilisation and reduced production performance. Similar to those studies, the present research identified several workstations operating under overload conditions, particularly in activities with high processing times and production demands. However, unlike previous studies that focused primarily on workload measurement using WLA, this study extends the analysis by incorporating CVL to evaluate workers' physiological responses [13]. The integration of WLA and CVL provides a more comprehensive understanding of both operational efficiency and worker fatigue, thereby supporting workforce planning decisions that consider productivity as well as worker well-being.

Based on the overall analysis, the company requires improvements in workforce allocation and workload balancing to optimise production performance. Additional workers are recommended for overloaded sections such as cutting, sewing, assembly, and finishing to reduce excessive workloads and improve production flow continuity. Furthermore, improvements in work methods, task redistribution, and production scheduling are also recommended to minimise bottlenecks and increase operational efficiency. Through these improvements, the company is expected to achieve more balanced workload conditions, enhance productivity, and fulfil production targets more effectively and sustainably.

To evaluate the potential effectiveness of the proposed workforce recommendations, a simple what-if analysis was conducted. By adding one operator to workstations classified as overloaded, the workload percentage at these stations would be distributed among additional workers, thereby reducing individual workload levels to within acceptable limits. For example, the workload at Sewing 4 would decrease from 127% to approximately 63.5% per worker, while Cutting 1 would decrease from 124% to approximately 62%. Similar reductions would be expected in other overloaded workstations, allowing production activities to be performed under more balanced working conditions.

The proposed workforce adjustment is also expected to improve operational performance by reducing bottlenecks in critical workstations. Current production output reaches approximately 4,700–4,800 pairs of sandals per month, while market demand is approximately 5,000 pairs. By reducing overload conditions in cutting, sewing, assembly, and finishing operations, production flow continuity can be improved and delays between workstations can be minimised. As a result, the company may increase its ability to fulfil customer demand, improve production efficiency, and enhance overall service performance. However, the results presented in this study are based on analytical projections and have not yet been validated through full-scale implementation or simulation modelling. Therefore, future studies are recommended to evaluate the proposed workforce allocation using simulation techniques or pilot implementation studies.

One limitation of the CVL analysis is that heart rate measurements may be influenced by individual factors such as age, physical fitness, and temporary health conditions. Nevertheless, the CVL method remains useful as a practical and widely accepted approach for assessing physiological workload in labour-intensive manufacturing environments. The integration of WLA and CVL results provides important insights into the relationship between operational workload and physiological workload. Workstations with WLA values exceeding 100% generally exhibited higher CVL percentages, indicating that excessive operational demands are associated with increased physical strain. This relationship demonstrates that workforce allocation decisions should not be based solely on productivity considerations but should also account for worker fatigue and physiological capacity. The combined use of WLA and CVL therefore offers a more comprehensive decision-support framework for workforce planning.

4. Conclusion

Based on the results of the workload and Cardiovascular Load (CVL) calculations, it was found that several production activities were operating under overload conditions as their workload values exceeded 100%, namely Cutting 1 at 124%, Sewing 1 at 106%, Sewing 2 at 117%, Sewing 3 at 108%, Sewing 4 at 127%, Assembly 3 at 102%, and Finishing 2 at 105%. These results indicate that the workload in several production processes has exceeded the workforce's capacity. Furthermore, the CVL calculations show that some workers are experiencing moderate to high levels of physical strain due to repetitive and continuous work activities throughout the production process. The high CVL values indicate an increase in workers' physical workload, which has the potential to cause work-related fatigue and affect concentration and the quality of production output if sustained over a prolonged period. Therefore, adjustments to the workforce and a more equitable distribution of work are required to ensure a more balanced working environment.

Based on calculations using the Workload Analysis (WLA) method, it has been established that several production activities require an increase in staffing to two operators, as they have a WLA value above 1 and are classified as being overloaded. These activities include Cutting 1, Sewing 1, Sewing 2, Sewing 3, Sewing 4, Assembly 3, and Finishing 2, where the workload in these processes has exceeded the normal working capacity of a single worker; therefore, additional operators are required to ensure a more balanced distribution of the workload and to enable the production process to run more optimally. Meanwhile, other production activities continue to utilise one worker as they have a WLA value of less than or close to 1, meaning they remain in normal or underloaded conditions, indicating that the workers' capacity is still sufficient to meet the demands of the work. With this adjustment to the number of workers, it is hoped that the workload balance, the smooth running of production processes, and the company's productivity can be optimally improved.

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