Workstation Design and Task Allocation in Assembly Lines

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ABSTRACT

This study evaluates workstation design principles, analyzes task allocation strategies, and assesses their impact on assembly line efficiency using a study approach of a Nigerian manufacturing firm specializing in electrical appliance assembly. The study involved direct observations, time-motion studies, and ergonomic assessments across 20 workstations. Workstation space utilization analysis revealed varying efficiency levels, with Workstation 5 achieving the highest utilization at 77.8%, while Workstation 4 had the lowest at 55.6%. Worker utilization data indicated that Worker 1 had the highest utilization rate at 90.0%, while Worker 3 had the lowest at 66.7%, highlighting inefficiencies in task distribution. Line balancing efficiency calculations showed Workstation 2 achieving an optimal 100.0% efficiency, whereas Workstation 3 recorded the lowest at 60.0%, indicating significant workload imbalances. Ergonomic risk assessment using the Rapid Upper Limb Assessment (RULA) method identified Workstation 2 as high risk with a score of 5, necessitating immediate ergonomic interventions. The findings suggest that optimizing workstation layout, redistributing tasks to balance workloads, and incorporating ergonomic interventions can enhance productivity and worker well-being. The study recommended implementation of adjustable workstations, standardizing cycle times, and integration of automation technologies to minimize inefficiencies.

Keywords: Workstation Design, Task Allocation, Assembly Line Efficiency, Ergonomics, Line Balancing

1. INTRODUCTION

Workstation design and task allocation significantly influence the efficiency, productivity, and ergonomics of assembly lines [1]. A poorly designed workstation can lead to inefficiencies such as excessive movement, bottlenecks, and worker fatigue, ultimately reducing throughput [2]. Effective workstation design ensures optimal space utilization, proper tool placement, and minimized worker strain [3]. It is highly required to create effective changes in workstations premised-based. Because this will make sure that employees work in safe environment, efficiently and at the least possible biological cost [4].

The design of the layout of the manufacturing industries is diverse with the presence of various types of manufacturing systems i.e. fully automated systems, semi-automated systems, completely human based systems and human and robot collaboration systems [5].

Task allocation plays a crucial role in balancing workloads and maintaining a steady production flow. Line balancing techniques, such as the Ranked Positional Weight (RPW) method and heuristic algorithms, have been developed to optimize task distribution [6], [7]. Line balancing has also considered that the workload should be balanced among the operators which makes an operator to have less idle time and simulation has also been carried out to study and validate the process [8]. Assigning the available resources is achieved through the task allocation. Safety is however not normally taken into account when assigning the task to the assembly system though it is essential to have the safety of the human operator when he/she is interacting with the robot [9]. Studies show that unbalanced workloads increase idle time and worker stress, negatively affecting overall performance [10].

Ergonomics is another key factor in workstation design. Poor ergonomic conditions can lead to musculoskeletal disorders (MSDs) and decreased worker efficiency [11]. The Rapid Upper Limb Assessment (RULA) method is widely used to evaluate ergonomic risks in workstation setups [12]. Research indicates that ergonomic improvements can enhance productivity by up to 20% while reducing worker injuries [13].

Despite advances in workstation optimization and task allocation, many manufacturing firms, especially in developing economies, still experience inefficiencies due to inadequate implementation of these principles [10]. New trends in the design of workstations focus on modularity

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and flexibility, Patel and Sanders have proven that layouts in lean facilities can be optimized using digital simulation tools that minimize wasted movement by 25% [11]. In the context of line balancing, heuristic optimization proved to be 15% more efficient than the traditional methods [12].

The modern ergonomics research places important emphasis on cognitive loads in workstation configuration, lobbied towards adjustable-height workstations to lessen the number of musculoskeletal disorders [13]. Besharati considered human factor calculations in all task allocation strategies, and the main idea was to choose the tasks relied on skills to avoid idle time [14]. This study aims to evaluate workstation design and identify inefficiencies, analyze task allocation and workload distribution and propose improvements for enhanced efficiency and ergonomics.

2. MATERIALS AND METHODS

2.1 Study Design

The study was conducted in a Nigerian manufacturing firm specializing in electrical appliance assembly. The production line consisted of 20 workstations (WS), with tasks ranging from component assembly to quality inspection. Workers were assigned based on skill levels and task complexity. Table I shows the information of a workstation in a Nigerian electrical appliance assembly firm. Workstations were chosen according to complexity of the work (ease of complexity) bottlenecks identified in the process of initial observations and varying space utilization (e.g. the lowest space was used in the WS3).

Table I: Workstation in a Nigerian Electrical Appliance Assembly Firm

Workstation ID	Name	Primary Tasks
WS1	Component Assembly Station	Mount motors, switches, and electronic parts onto appliance bodies
WS2	Wiring & Electrical Connection	Solder wires, connect terminals, attach circuit boards
WS3	Fastening & Mechanical Assembly	Fit panels, screw casings, attach knobs and control units
WS4	Quality Control & Testing	Inspect, test voltage/current, functional checks (e.g., fan speed, heating)
WS5	Labeling & Packaging	Print and apply labels, seal units, box for shipment

2.2 Data Collection

An analysis was conducted to evaluate the workstation design and task allocation within an assembly line environment. Data collection methods included direct observation, work sampling, and time-motion studies to assess workstation efficiency and workload distribution.

The study employed a case study approach to examine workstation design and task allocation in an assembly line environment. Data collection involved direct observation, work sampling, and time-motion studies to evaluate workstation efficiency and workload distribution. The research was conducted at a Nigerian manufacturing firm specializing in electrical appliance assembly. The production line comprised 20 workstations, where tasks ranged from component assembly to quality inspection. Workers were assigned tasks based on their skill levels and the complexity of the work.

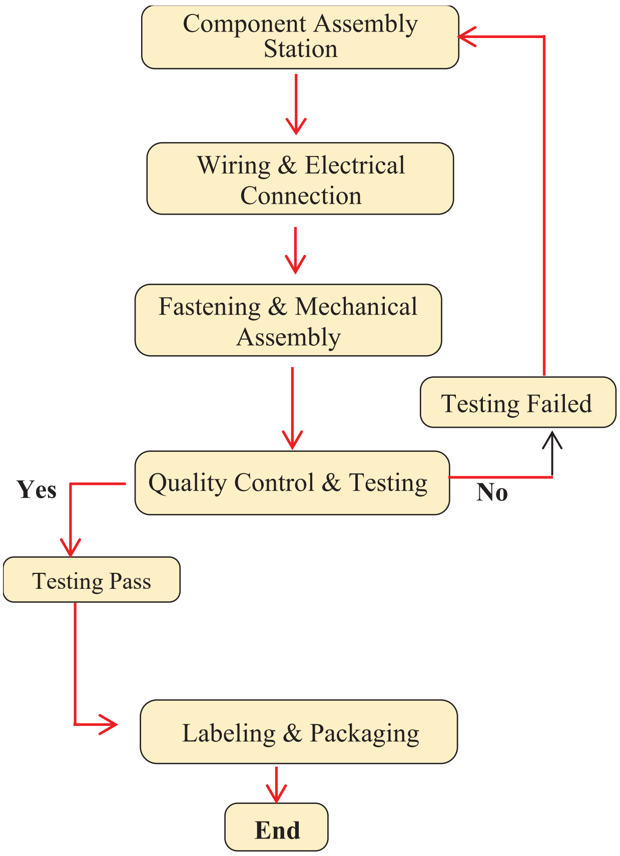

Fig. 1: Simplified Process Flow Diagram of the Assembly Line, Highlighting Material and Task Sequences

To assess workstation efficiency, measurements were taken to evaluate space utilization. Observations focused on worker posture, the accessibility of tools, and the placement of materials. Additionally, ergonomic risks were identified using the Rapid Upper Limb Assessment (RULA) method. For task allocation analysis, time studies were performed to determine task duration, while work sampling was used to assess worker utilization rates and idle time.

2.2.1 Raw Data and Calculations for Time Studies

2.2.1.1 Workstation Space Utilization

Workstation Space Utilization means the success of utilizing the given place dedicated to a workstation by beneficial operations. It is of assistance in assessing the effectiveness of layout plan in production or bulk-assembly set up. Utilization of work stations is expressed as the ratio between actual space that is occupied by tools and equipment as well as workers in comparison to the total work station space.

$$\text{Utilization (\%)} \ \frac{\text{Space Utilized (m2)}}{\text{Space Available (m2)}} \times 100 \tag{1}$$

2.2.1.2 Worker Utilization Analysis

This is the technique applied to determine whether time of a worker is being well utilized in any production or assembly line. It is a ratio or a percentage of time that a worker actively spends within performing his/her duties to the sum overall time the worker has (including that spent idle).

The control of human resource in an environment of production cannot be achieved without the analysis of Worker Utilization. It assists one to match manpower with work requirements and where the process requires re-engineering, training or automation.

$$\text{WU (\%)} \ \frac{\text{TsT}}{\text{TsT + Id T}} \times 100 \tag{2}$$

Where,

WU is Worker Utilization

TsT is Task Time

IdT - Idle Time

Task balancing was evaluated using the Line Balancing Efficiency (LBE) formula, which considers total work time, the number of workstations, and cycle time [15].

$$\text{LBE} = \frac{\sum \text{Tw}}{\text{N} \times \text{Tc}} \times 100 \tag{3}$$

Where,

T_w is total work time,

N is the number of workstations,

T_c is the cycle time.

2.2.2 Data Collection Protocol

2.2.2.1 Time-Motion Studies

Time-Motion Studies is carried out during 50 cycles of production (5 cycles per workstation x 10 shifts).

2.2.2.2 Worker Demographics:

Levels of Skills: 60% intermediate (1-3 years) and 40% advanced (more than 3 years).

2.2.2.3 Shift Patterns

There were two shifts (8 hours each) per day, and the data was collected during both in order to take the fatigue into consideration.

2.2.3 Process Constraints

It had fixed cycle time of 50 minutes that was determined by the processing activities upstream and the constraints on the ability to alter tool location because of safety standards.

The collected data was analyzed to assess workstation efficiency based on space utilization and ergonomic factors. Task allocation efficiency was evaluated by comparing the actual workload distribution with an ideal balanced scenario. Furthermore, statistical tools such as SPSS were applied to examine variations in task completion times across different workstations.

3. RESULTS

The study employed a case study approach to analyze workstation design and task allocation in an assembly line setting. The data collection methods included direct observations, work sampling, time-motion studies, and ergonomic assessments to evaluate workstation efficiency, workload distribution, and worker well-being. The research was conducted in a Nigerian manufacturing firm that specializes in electrical appliance assembly. The production line consisted of 20 workstations where workers were assigned tasks based on their skill level and task complexity to ensure an efficient workflow [3].

To assess workstation efficiency, the study measured space utilization and conducted observations to evaluate worker posture, tool accessibility, and material placement. The ergonomic risks associated with workstation design were analyzed using the Rapid Upper Limb Assessment (RULA) method, which is a widely used tool for identifying postural and movement-related risk factors [10]. For task allocation analysis, time studies were conducted to determine task duration, while work sampling was used to assess worker utilization rates and idle time. The Line Balancing Efficiency (LBE) formula was applied to quantify how effectively workloads were distributed across workstations.

3.1 Workstation Space Utilization

Table II presents the space availability and utilization rates for selected workstations in the assembly line. The analysis highlights variations in how effectively each workstation utilizes its allocated space, which contributes to inefficiencies in workflow and ergonomic challenges.

Table II: Workstation Space Utilization Analysis

Workstation	Space Available (m^2)	Space Utilized (m^2)	Utilization (%)
WS1	45	30	66.7
WS2	45	32	71.1
WS3	45	28	62.2
WS4	45	25	55.6
WS5	45	35	77.8

Table II provides an analysis of workstation space utilization in the assembly line, showing the available space, the actual space utilized, and the corresponding utilization percentage for each workstation. The data highlights variations in how efficiently each workstation uses its allocated space, which directly impacts workflow, worker movement, and productivity [1].

Each workstation in the study was allocated a uniform space of $45m^2$. However, the actual utilization varied across different workstations. Workstation 1 utilized $30m^2$, resulting in a 66.7% utilization rate, indicating moderate space efficiency with potential room for optimization. Workstation 2 had a slightly higher utilization rate of 71.1%, using $32m^2$, suggesting a relatively better-organized workstation. Workstation 3 exhibited the lowest utilization, using only $28m^2$, which translates to a 62.2% utilization rate. This may indicate inefficient space allocation or poor workstation arrangement. Similarly, Workstation 4 had a lower utilization rate of 55.6%, using $25m^2$, suggesting a no too good-organized workstation. On the other hand, Workstation 5 recorded the highest utilization at 77.8%, implying a well-optimized workstation layout with minimal wasted space. Studies have shown that unoptimized workstation layouts contribute to excessive worker movement, lower efficiency, and increased cycle times [2]. The variation in space utilization among the workstations has significant implications for productivity and efficiency. Underutilized workstations may lead to excessive worker movement, resulting in wasted time and increased fatigue. Conversely, workstations with very high utilization rates could be overcrowded, restricting movement and creating ergonomic challenges [3]. Poor organization of tools and materials in low-utilization workstations can further contribute to inefficiencies in workflow, leading to delays and increased idle time [6]. Research suggests that proper space management and ergonomic workstation design can improve productivity by up to **20%** while reducing worker fatigue and injury risks [11].

3.2 Task Allocation and Worker Utilization

Table III presents an analysis of worker utilization rates based on time-motion studies, highlighting the task assigned, task duration, idle time, and overall utilization percentage for each worker. This study provides insight into the efficiency of task distribution and helps identify areas for improvement in balancing workloads to enhance overall assembly line performance.

Table III provides an overview of worker utilization in the assembly line by detailing the assigned tasks, task duration, idle times, and overall utilization percentages. The analysis highlights variations in worker efficiency, revealing potential imbalances in task allocation that could impact overall productivity.

The result shows that Worker 1, assigned to component assembly, completed tasks in 450 minutes and had 50 minutes of idle time, resulting in a 90.0% utilization rate. This high utilization indicates an effectively assigned workload with minimal downtime. Worker 2, responsible for wiring and electrical connection, had a task time of 500 minutes and an idle time of 100 minutes, leading to a utilization rate of 83.3%. This suggests a relatively balanced workload, although minor adjustments could further optimize efficiency. Worker 3, performing fastening and mechanical Assembly, exhibited the lowest utilization rate at 66.7%, with a task time of 300 minutes and 150 minutes of idle time. This indicates significant under-utilization, likely due to either task redundancy, process inefficiencies, or improper workload distribution.

Table III: Worker Utilization Analysis

Worker ID	Assigned Task	Task Time (mins)	Idle Time (mins)	Utilization (%)
W1	Component Assembly	450	50	90.0
W2	Wiring & Electrical Connection	500	100	83.3
W3	Fastening & Mechanical Assembly	300	150	66.7
W4	Quality Control & Testing	450	65	87.4
W5	Labeling & Packaging	500	82	85.9

The result further shows that Worker 4, assigned to quality control and testing, completed tasks in 450 minutes and had 65 minutes of idle time, resulting in a 87.4% utilization rate. This high utilization also indicates an effectively assigned workload with minimal downtime. Worker 5, responsible for labeling and packaging had a task time of 500 minutes and an idle time of 82 minutes, leading to a utilization rate of 85.9%.

The varying worker utilization rates in Table III suggest an imbalance in task distribution, which can negatively impact assembly line performance. High utilization rates, as seen with Worker 1, Worker 4 and Worker 5 indicate effective task allocation, ensuring minimal idle time and steady workflow [6]. However, excessive workloads can also lead to worker fatigue, reduced efficiency, and increased error rates over time [11].

Conversely, the lower utilization rate of Worker 3 highlights inefficiencies that may result in wasted production time and underperformance. Studies suggest that worker idle time exceeding 20% can lead to a 5-15% reduction in overall assembly line efficiency, as it disrupts workflow continuity and increases lead times [8]. Furthermore, uneven task distribution can create bottlenecks in the production line, leading to delays in subsequent processes [15].

3.3 Line Balancing Efficiency

Table IV presents the line balancing efficiency (LBE) for selected workstations, highlighting the relationship between work time, cycle time, and efficiency percentage. This analysis helps identify inefficiencies in task distribution and provides insights into optimizing workstation performance to achieve a more balanced and efficient assembly line.

Table IV: Line Balancing Efficiency

Workstation	Work Time (mins)	Cycle Time (mins)	LBE (%)
WS1	45	50	90.0
WS2	50	50	100.0
WS3	30	50	60.0
WS4	40	50	80.0
WS5	45	50	90.0

Table IV presents the Line Balancing Efficiency (LBE) for selected workstations, showing the relationship between work time, cycle time, and efficiency percentage. Line balancing is a crucial factor in optimizing assembly line performance, as an imbalance can lead to bottlenecks, idle time, and productivity losses [6]. The data in Table III reveals variations in efficiency across different workstations, indicating areas that require improvement to enhance overall production flow.

The results indicate that Workstation 1 had a work time of 45 minutes and a cycle time of 50 minutes, yielding a line balancing efficiency of 90.0%. This suggests an effectively utilized workstation with minimal idle time. Workstation 2 exhibited the highest efficiency at 100.0%, meaning its task allocation perfectly matched the cycle time, ensuring continuous workflow without delays. However, Workstation 3 recorded the lowest efficiency at 60.0%, with a work time of 30 minutes against a cycle time of 50 minutes, highlighting a significant imbalance that may contribute to production inefficiencies.

The results further shows that Workstation 4 had a work time of 40 minutes and a cycle time of 50 minutes, yielding a line balancing efficiency of 80.0%. This suggests there is an effective utilization of workstation with minimal idle time. Workstation 5 also exhibited the high efficiency at 90.0%, meaning that the task allocation of 45 minutes and the cycle time of 50 minutes, yielding a line balancing efficiency, ensuring continuous workflow without delays.

The disparities in line balancing efficiency across workstations have direct consequences on assembly line performance and worker utilization. A workstation with high efficiency, like Workstation 2, ensures a smooth production flow, reducing delays and optimizing resource utilization [15]. However, low efficiency, as seen in Workstation 3, suggests under-utilization, which can cause bottlenecks at subsequent workstations, leading to an uneven workload distribution and reduced overall system efficiency [8]. Studies show that an LBE below 70% can reduce production output by up to 15%, as unbalanced workloads increase cycle time variations and disrupt workflow synchronization [13].

Furthermore, inefficiencies in line balancing can lead to worker fatigue and increased operational costs. Overloaded workstations force workers to rush tasks, increasing error rates, while under-loaded stations cause unnecessary downtime and productivity losses [8]. To achieve an optimal balance, task redistribution and line balancing techniques, such as the Ranked Positional Weight (RPW) method and heuristic algorithms, should be employed to distribute workloads more evenly [15].

3.4 Ergonomic Risk Assessment

Table V presents the Rapid Upper Limb Assessment (RULA) scores for selected workstations, indicating the level of ergonomic risk associated with each workstation setup. Analyzing these scores, potential ergonomic hazards can be identified, and appropriate interventions can be recommended to improve worker well-being and optimize workstation design.

Table V: Ergonomic Risk Assessment Results

Workstation	RULA Score	Risk Level
WS1	4	Medium
WS2	5	High
WS3	3	Low
WS4	3	Low
WS5	4	Medium

Table V presents the Rapid Upper Limb Assessment (RULA) scores for selected workstations, highlighting the ergonomic risks associated with each workstation setup. Ergonomic assessments are crucial in identifying postural risks, worker discomfort, and potential musculoskeletal disorders (MSDs), which can negatively impact worker productivity and well-being [10]. Table IV reveals varying levels of ergonomic risk, emphasizing the need for workstation adjustments to enhance comfort and efficiency. The results show that Workstation 1 received a RULA score of 4, indicating a medium risk level that requires further investigation and possible ergonomic interventions. Workstation 2 recorded the highest risk, with a RULA score of 5, categorizing it as a high-risk workstation that demands immediate ergonomic improvements. This score suggests that workers at this station may be experiencing poor posture, excessive force exertion, or repetitive motion stress, which could lead to musculoskeletal strain and long-term injuries if not addressed [9]. Conversely, Workstation 3 had the lowest RULA score of 3, indicating a low-risk level where ergonomic conditions are relatively acceptable, though minor improvements could still be beneficial. The results further reveals that Workstation 4 received a RULA score of 3, indicating a low risk level that requires further investigation and possible ergonomic interventions. Workstation 5 recorded the medium risk, with a RULA score of 4, categorizing it as a medium-risk workstation that demands immediate ergonomic improvements. This score suggests that workers at this station may be experiencing poor posture, excessive force exertion, or repetitive motion stress, which could lead to musculoskeletal strain and long-term injuries if not addressed [9].

The presence of high ergonomic risk in Table IV suggests that certain workstations may contribute to worker discomfort, reduced efficiency, and increased injury rates. Studies have shown that workstations with poor ergonomic design can lead to a 20-30% reduction in productivity, as workers experience fatigue, discomfort, and potential health issues that affect their ability to perform tasks effectively [11]. Additionally, prolonged exposure to awkward postures and repetitive movements has been linked to increased cases of lower back pain, wrist injuries, and shoulder strain, which are common in assembly line operations [16]. Workstation 2's high RULA score is particularly concerning, as it may indicate poor seating posture, excessive reaching distances, or improper tool placement. Research suggests that workers exposed to high ergonomic risks are more likely to suffer from work-related MSDs, which not only affect individual performance but also contribute to higher absenteeism rates and increased healthcare costs for employers [17].

4. DISCUSSION

Table II presents the workstation space utilization analysis, which examines the relationship between available space, utilized space, and utilization percentage. Workstation efficiency plays a crucial role in manufacturing operations, as poor space management can lead to excessive worker movement, workflow inefficiencies, and increased fatigue [6]. Underutilized workstations can result in unnecessary worker movements, workflow disruptions, and inefficiencies in production, while overcrowded workstations may lead to ergonomic strain and restricted movement [7]. Studies indicate that optimizing workstation layout and tool placement can improve productivity by up to 15% by minimizing physical exertion and enhancing workflow organization [3]. To address these inefficiencies, adjustments should be made to workstation layouts, tool positioning, and material placement. Implementing ergonomic interventions, such as adjustable workstation heights and anti-fatigue flooring, can further enhance worker comfort and overall productivity [9].

Table III presents an analysis of worker utilization, which highlights how task allocation impacts worker efficiency. Worker utilization is a critical factor in assembly line performance, as imbalanced workloads can lead to bottlenecks, increased idle time, and worker fatigue [10]. Studies suggest that workers with utilization rates below 70% often contribute to production delays and reduced efficiency, as idle time disrupts workflow synchronization and increases cycle time variability [11]. Task allocation imbalances can also lead to worker fatigue, increased error rates, and reduced product quality, all of which negatively impact operational efficiency [12]. To enhance worker utilization, the study recommends task redistribution strategies that ensure even workload distribution across workstations. Additionally, process optimization techniques, such as eliminating redundant steps and improving task sequencing, can streamline workflows [13]. The integration of semi-automated systems can also help reduce worker strain, improve efficiency, and minimize task completion times [14].

Table IV presents the Line Balancing Efficiency (LBE) calculations, which measure the effectiveness of task distribution across workstations. A well-balanced assembly line minimizes idle time, reduces bottlenecks, and ensures continuous workflow [13]. An unbalanced assembly line contributes to worker fatigue, bottlenecks, and longer cycle times, which ultimately reduces production efficiency [16]. Research suggests that LBE values below 70% correlate with a 10 to 20% decrease in overall production output due to workflow disruptions and excessive idle time [18]. To improve line balancing efficiency, tasks should be reallocated evenly across workstations to minimize idle time [19]. Standardizing cycle times across workstations and integrating real-time monitoring systems can also help track inefficiencies and optimize workload distribution [20].

Table V presents the RULA scores for ergonomic risk assessment, which highlights postural risks and ergonomic deficiencies across workstations. Poor ergonomic conditions can lead to musculoskeletal disorders (MSDs), worker discomfort, and decreased productivity [8]. Studies show that ergonomic improvements can enhance worker comfort, reduce injury risks, and increase productivity by up to 20% [18]. To address ergonomic risks, workstations should be adjustable in height to accommodate different worker postures [18]. Providing anti-fatigue mats, wrist supports, and adjustable chairs can also help reduce strain on workers [19]. Additionally, structured break intervals should be introduced to prevent repetitive strain injuries and allow workers time to recover from physically demanding tasks [20].

The study highlights inefficiencies in workstation design, task allocation, line balancing, and ergonomic conditions in an assembly line. The findings emphasize the importance of optimizing space utilization, balancing workloads, and improving ergonomic conditions to enhance overall productivity. Implementing task redistribution strategies, ergonomic interventions, and automation can significantly reduce idle time, enhance efficiency, and improve worker well-being [20].

5. CONCLUSION

The study examined the impact of workstation design, task allocation, line balancing, and ergonomic factors on assembly line efficiency. The findings revealed that inefficient workstation layouts, unbalanced task distribution, and poor ergonomic conditions contribute to reduced productivity, increased worker fatigue, and operational inefficiencies. The analysis of workstation space utilization showed that some workstations were underutilized, leading to unnecessary worker movements and workflow disruptions, while others were overcrowded, restricting worker comfort and efficiency [21]. The worker utilization analysis highlighted imbalances in task assignments, with some workers experiencing excessive idle time while others were overburdened, resulting in decreased overall productivity. The line balancing efficiency assessment indicated significant disparities among workstations, with some achieving optimal efficiency while others exhibited severe inefficiencies that disrupted the production flow [22]. The ergonomic risk assessment further identified workstation setups that posed significant health risks to workers, increasing the likelihood of musculoskeletal disorders and reducing efficiency.

To address these inefficiencies and improve overall assembly line performance, several recommendations should be implemented. Workstation layouts should be optimized to ensure efficient space utilization, reduce unnecessary worker movements, and enhance accessibility to tools and materials. Task redistribution strategies should be employed to balance workloads effectively, minimizing idle time and preventing overburdening of workers [23]. Line balancing techniques, such as the Ranked Positional Weight (RPW) method and heuristic optimization algorithms, should be utilized to ensure an even distribution of tasks across all workstations. Ergonomic interventions, including the introduction of adjustable workstations, proper seating, and anti-fatigue flooring, should be implemented to reduce physical strain and enhance worker comfort. Additionally, automation and digital monitoring tools should be incorporated into the production process to improve task efficiency, minimize human errors, and maintain consistent cycle times [24].

The study underscores the importance of integrating efficient workstation design, balanced task allocation, optimized line balancing, and ergonomic best practices to enhance productivity and worker well-being in assembly line operations. Adoption of these recommendations, manufacturing firms will improve efficiency, reduce operational costs, and create a safer and more productive working environment for employees.

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