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Optimizing Productivity Through the Application of Ergonomics in an Automotive Manufacturing Organization

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Abstract

Ergonomics plays a vital and central role in the operations of manufacturing companies, serving as a foundation for ensuring the efficiency of production processes, as well as the well-being and safety of the workforce. This research study investigates the application of ergonomic principles to optimize the production process, with a specific focus on addressing the challenges of meeting cycle time and daily output targets. The primary issue identified in this study is the recurrent inability to achieve required cycle times in the production process, which in turn significantly impacts the daily volume targets. To address this issue comprehensively, a mixed-method approach is adopted. The findings of this research revealed several ergonomic challenges including repetitive motions, inadequate or absent tooling, and task sequencing. Through the analysis of the data and a comprehensive evaluation of the workstations' ergonomics, it became evident that the existing ergonomic setups were the primary contributors to the delayed cycle times hence affecting productivity in the organization. When the ergonomics were further broken down into specific issues, it was discovered that the workers were facing difficulties when it came to segregating a group of identical parts due to their tightly packed nature. Worker feedback highlighted discomfort, fatigue, and an increased risk of musculoskeletal disorders due to these ergonomic issues. Implementing strategic ergonomics interventions will lead to improved workplace productivity and, consequently, higher daily production outputs.

Keywords
Ergonomics, Safety, Automotive Industry, Risk and Fatigue.

1. Introduction
The automotive industry is characterized by highly demanding and repetitive tasks that can lead to physical strain and reduced productivity. Due to the industry's high dynamic nature and competitiveness, there is a necessity to find ways to optimize productivity to accomplish targeted cycle times and daily production. Bridge (2008) defined ergonomics as the study of how people interact with machines and the variables that influence that relationship.South African

automotive company XY incorporates ergonomics into their front wheelhouse production line since it encompasses the interaction between humans, machines, and the environment. It has been discovered that multiple stations on this particular manufacturing line are not meeting the daily production needs and the established cycle time, which has a negative influence on the line's productivity. Because ergonomics has a significant impact on a company's overall productivity, its application and relevance will benefit the organization.

The company's front wheel production line has a cycle time of 191 seconds, and it operates continuously for 24 hours a day, seven days a week. Given this cycle time, an estimated 15 units per hour are required from the production line, 108.75 units are required per 8-hour shift and 326.25 units are required per day (3, 8-hour shifts). In actual fact, the production line is only able to produce 14 units per hour at an average cycle time of 201.7 seconds. Given this hourly rate, the company is able to produce 102.62 units per 8-hour shift and 307.87 units per day. Therefore, this results in a deviation of 18 units between the required output and the actual production output due to the increased cycle time. The production line is essential to the body shop process, and when it doesn't reach the target cycle time; bottlenecks, production delays, increased costs, and the business's ability to satisfy client requests are all impacted.

In a perfect world, every station along the front wheelhouse production line would complete the cycle in 191 seconds, meeting the daily output goals. However, due to poor ergonomics designs, these stations constantly encounter longer cycle times. It is through this analysis that the primary purpose of this study was established, which was to investigate how the application of ergonomics principles can be utilized to optimize productivity within the front wheelhouse production line.

1.1 Objectives

The aim of the study is to apply ergonomics to optimize productivity through evaluating and optimizing the ergonomic design of workstations, tools and equipment. The study seeks to reduce physical strain on employees ultimately leading to improved efficiency. This aim will be achieved through meeting the following objectives: by identifying critical ergonomic factors affecting the cycle time and modifying processes to achieve the cycle time.

2. Literature Review

Ergonomics is described as the study of how humans interact with machines and the variables that influence that relationship (Bridger 2018, Chaffin 2006). The goal of ergonomics is to improve human health and the overall performance of the human system through the application of principles of human physiology, physiognomy, and engineering to design and implement products, processes, and workplaces that suits human capabilities and limitations (Chaffin 2006). The goal of ergonomics is to enhance the interaction between people and machines in order to increase system performance (Bridger 2018).

Salvendy and Karwowski (2021), highlighted the crucial role that ergonomics plays in manufacturing firms namely optimizing the fit between the employee, the tasks they perform, and their workspace. Incorporating ergonomics in design of processes and layouts of production facilities; companies may improve workflow, reduce errors, and minimize fatigue, all of which contribute to a higher productivity and efficiency of an organization (Salvendy and Karwowski 2021, Chaffin 2006).

Toyota and Volkswagen are amongst the top automotive companies that have implemented ergonomics to improve their productivity. Toyota Production System (TPS) has significantly reduced ergonomic risk factors and improved worker productivity through techniques such as job rotation, standardized work procedures, and employee involvement in problem-solving (Lee at al 2019). Volkswagen introduced a program at its production facilities focusing on improving worker safety and productivity. This program included ergonomic work design, employee training, and routine evaluations which then yielded a significant decrease in musculoskeletal disorders and an improvement in worker productivity (Liker 2019).

2.1 Relevance of ergonomics in the automotive industry

Ergonomics plays an important role in the automotive industry, from the design and manufacturing of a unit to driver safety and maintenance, and is a vital tool in improving the safety and comfort of those working in the automotive industry (Liker 2019, Lee et al 2019, Chen 2017). In the automobile g process, ergonomics is used in a variety of stages, such vehicle design, manufacturing and assembly, human-machine interface (HMI), and maintenance and repair (Chen 2017).

There are a number of basic principles and concepts that guides the design and arrangement of various components to make them more ergonomically suitable for human use. Effective workstation design and layout are fundamental to ergonomic principles in the automotive industry by promoting a neutral body position and reduce excessive reaching, bending, or twisting motions which then promotes worker comfort and minimizes the risk of musculoskeletal disorders (MSDs) (Karakolis and Callaghan 2013). Ergonomically designed tools and equipment are crucial for worker safety and efficiency in the automotive manufacturing process. The selection and design of hand tools, power tools, and assembly equipment can significantly impact worker comfort and productivity (Gualtieri et al 2020). Additionally, lowering the risk of manual handling injuries is a major priority in the automotive industry. This emphasizes the need for ergonomics to design processes and equipment that reduce the amount of manual lifting, carrying, and pushing and pulling of heavy materials or components (Jang 2020).

2.2 Productivity enhancement through Ergonomics

By creating ergonomically optimized workplaces, tools and equipment; employees can work easier and comfortably with less physical strain. As a result, this helps employees maintain a high level of attention and engagement throughout their work, thus improving productivity and performance (Rempel 2008). Ergonomics principles can reduce musculoskeletal disorders, fatigue, and discomfort; which in turn can also improve productivity of an organisation (MacLeod 1994). It is evident that the human body is an important aspect in the field of ergonomics therefore a thorough understanding of human anatomy is needed to make better decisions about the human body's capabilities and limitations.

The automotive industry can additionally improve output and increase productivity by arranging workstations optimally to suit workers and reduce the number of non-value-added activities such as repetitive motions that reduces productivity. The simplification of work procedures and reduction of repetitive motions are some of the ergonomic related ways to shorten cycle time which then enables workers to execute activities more quickly, reduces cycle times and decreases the need for repetitive and time-consuming operations (Chen 2017).

Ergonomic interventions such as better workstation design, adjustable chairs, desks, adjustable keyboards and monitors lead to significant improvements in task completion times, reduced discomfort, reduced musculo-skeletal symptoms, and decreased cycle times resulting in increased overall work efficiency (Hedge et al 2010). Maximizing interactions between employees and their surroundings, ergonomics, can assist organizations in meeting daily output objectives, lessen the incidence of unneeded delays, allowing for the accomplishment of production goals by making sure that stations, tools, and equipment are correctly built and modified to satisfy the demands of workers (Mistovich and Haven 2017).

3. Research Methods

A mixed-method research approach was utilized in this study were both qualitative and quantitative data were obtained. The data was collected through on-site visits, field observations, questionnaires and secondary data extracted from the company's software programs (SAB and SERA). The research began with a time study that took a quantitative approach to determine the actual amount of time required to complete the tasks in comparison to the predetermined cycle time as per the company's set standard.

The field observations and questionnaires (Annexure A and B) allowed the observation and analysis of the current work practices, workflows and ergonomic issues. This gave a comprehensive understanding of the relationship between ergonomics and productivity and enabled for accurate interpretation of the data. The questionnaire was utilized specifically to collect data directly from the workers at the front-end wheelhouse stations in the plant. The primary objective of the survey was two-fold: firstly, to comprehensively assess and document the existing conditions and circumstances within the front-end wheelhouse area and secondly, to solicit valuable insights and opinions directly from the workers who are actively engaged in the production process on the shop floor. The questions of the survey were aimed at identifying the potential factors or causes contributing to delays in cycle time, as perceived and reported by the shop floor workers themselves. The survey consisted of both qualitative and quantitative questions, which were strategically formulated to draw out specific information. The quantitative section of the survey featured questions with predefined response options, facilitating the collection of numerical data that could be subjected to statistical analysis. These questions were geared towards quantifying aspects such as frequency of cycle time delays, and frequency of achieving the cycle time. In addition to the quantitative questions, the survey also included qualitative questions that encouraged open-ended responses from the workers. These qualitative questions sought to uncover insights, experiences, and perspectives that might not be captured by quantitative data alone. The workers were prompted to describe any specific challenges they encountered with regards to achieving the set cycle times and how these challenges might be linked to the observed cycle time delays.

Additional data was extracted from two company programs called SERA and SAB. SERA (Safety & Ergonomics Risk Analysis) provided qualitative and quantitative data relating to ergonomic analysis of the production line. The program analyzed the different regions of the body to determine the strain endured by each and also examined the physical ergonomics of the human body while a worker executes the task. This program was designed to define and establish the standards for what constitutes a good, ergonomic, and healthy production workplace. It shows a numerical score that illustrates the extent to which the various bodily components are strained as well as a visual representation of the degree of the strain. The rating score indicates whether the part is stressed to an acceptable degree or not.

A SAB tool is an in-house tool that was used for calculating the cycle times for the Front-End Wheel Stations. The company considers SAB to be a more reliable method for calculating cycle times compared to traditional stopwatches, it can provide more accurate and consistent results and also monitors the utilization of workers. SAB keeps track of how effectively and efficiently workers are using their time while performing tasks at the Front-End Wheel Stations.

4. Data Collection

On-site visits, field observations, questionnaires and SAB programs were the methods used to collect the data. The data was analyzed using cause-effect-diagram, pareto analysis, and SERA ergonomics tools.

5. Results and Discussion

5.1 Questionnaires

The survey questionnaire results showed that achieving cycle time was not only a challenge but was also noticeable to the workers themselves. Survey 1 highlighted various factors that affected cycle time, with ergonomics being the most significant one. This prompted the need for a follow-up survey, which was employed to gain more detailed insights into the ergonomics challenges.

In Survey 2, the ergonomics issue was pursued further by asking the employees about the particular ergonomic problems that were negatively impacting and preventing them from meeting the predetermined cycle time in the front-end wheelhouse production line. The findings from survey 2 revealed issues related to the sequencing of work instructions and the excessive movements required as contributors of reduced cycle time in the front-end wheelhouse production line. The data from the survey was utilized to identify possible causes of reduced cycle time in order to formulate a cause-and-effect diagram.

5.2 Cause-and-effect diagram

Figure 1 shows a visual representation outlining possible causes of cycle time delays at the front-end wheelhouse stations. Within each major category are the sub possible causes depicted in the figure which would then be analysed using a pareto chart to determine which factors might be the most significant or impactful in causing the cycle time delays.

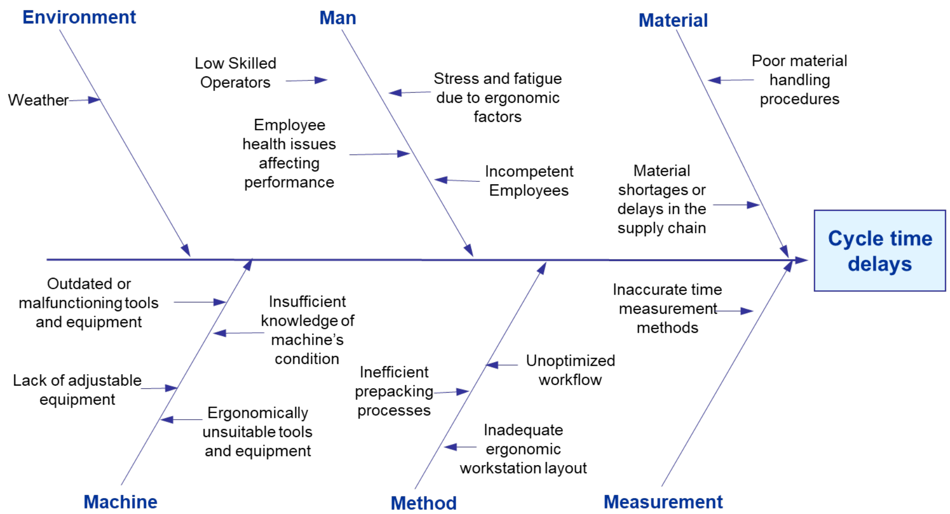


Figure 1. Possible causes for delayed cycle time

5.3 Root Cause Analysis

Figure 2 shows the most probable to the least probable causes of delayed cycle time at the front-end wheelhouse stations. The possible causes of delayed cycle time were extracted from the surveys and the cause-and-effect diagram (Figure 1).

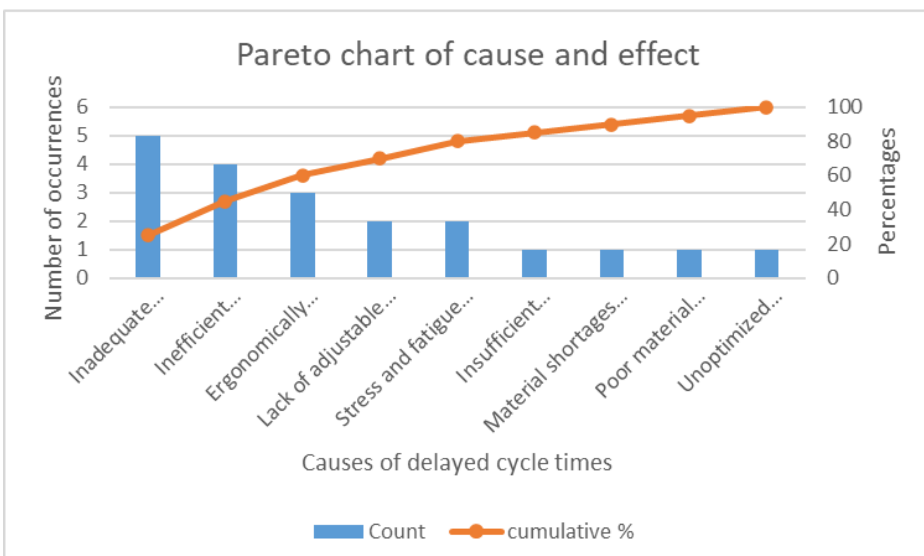


Figure 2. Pareto analysis for causes of delayed cycle times

Inadequate ergonomic workstation layout was the most frequent cause of delayed cycle time in the production line. The data collected revealed that the components or parts required for the tasks at the workstations were situated too far away from the worker's immediate reach. This necessitated extra movement, stretching, or walking to retrieve the needed parts, which in turn significantly extended the cycle time. In addition to taking more time, the increased distance also contributed to fatigue and errors. Fatigue decreases productivity, concentration, and overall efficiency, further contributing to delayed cycle time.

The second highest cause of delayed cycle time was inefficient prepacking processes. As part of the standard work instruction for operating all four front-end wheelhouse station, the worker was required to collect the parts individually during an activity instead of prepacking prior to starting the activity which represented inadequate ergonomic workstation layout. The workers had to spend extra time picking or handling each component one at a time and this process was found to be slow, error-prone, and labor-intensive.

Tooling issues was the third most frequent cause of delayed cycle time at the workstation. The data collected showed that one of the sub-parts came in a batch that were closely attached or tightly packed and had to be manually separated before use without any tooling assistance. Having to separate the batch requires manual force which is a time-consuming task thereby adding significant time to the overall cycle time. This finding also highlighted inefficiencies within the workflow and whereby extra time and labor were required for the manual separation rather than workers focusing on the core production tasks at hand.

5.4 SAB results

The front-end wheelhouse operations involves a collaboration between humans and machines (robots), whereby workers load parts into the station and await the completion of the robotic cycle. Figure 1 illustrates the results obtained from the SAB program. When the process steps were captured into SAB, it automatically calculated the cycle time to complete the task in relation to the predetermined cycle time. In this instance, the system computed a cycle time of 197 seconds, which is more than the standardized cycle time of 191 seconds for these workstations. Additionally, SAB computed the utilization rate using a specific equation, yielding a result of 103%, which signified that the cycle time had been exceeded.

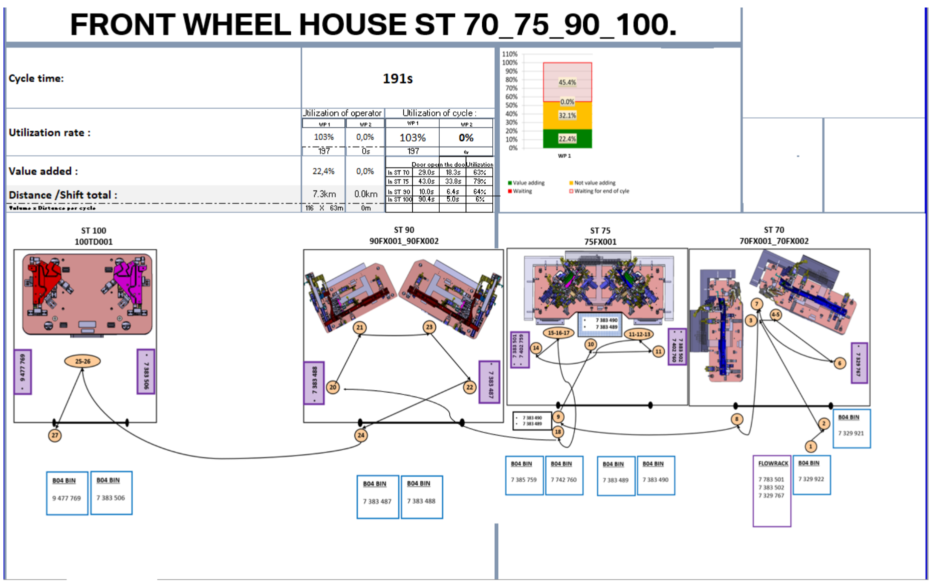
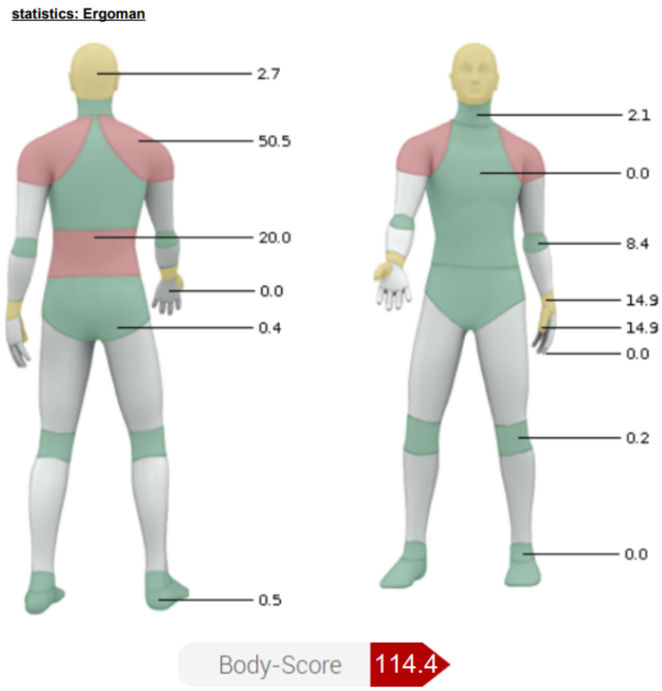


Figure 3. SAB results

SAB showed that only 22.4% of the activities were value-adding, while the rest were non-value-adding. Furthermore, the waiting time for the cycle to finish was 45.4%, and was categorized as a non-value-adding activity. Other non-value-adding activities, such as excessive walking and the separation of tightly packed components, accounted for 32.1% of the cycle time. This is a clear indication that these ergonomics issues are critical since they make up a large portion of the cycle time.

5.5 SERA Findings & Analysis

The SERA analysis indicated that the potential hazards and ergonomic challenges that a worker at front-end wheelhouse stations experienced were that parts were placed at a distant location requiring excessive motion and making it difficult to separate them. With parts located at a considerable distance from the workstations, workers were forced to perform tasks that involve excess motion to access these parts, posing risks to workers, particularly straining their shoulders, legs, and hands. The score that illustrates the extent to which the various bodily regions are strained as well as a visual representation of the degree of the strain are shown in the figure below, Figure 4.



Body part	Body-Score
Head	2.7
Neck	2.1
Shoulder	50.5
Thorax	0.0
Back	20.0
Hip	0.4
Elbow	8.4
Wrist	14.9
Palm of Hand	0.0
Thumb	14.9
Finger	0.0
Knee	0.2
Ankle	0.0
Foot	0.5

Figure 4. Visual representation of bodily strains (SERA results)

The data show that the following body parts or regions in red are under significant strain, Figure 5.

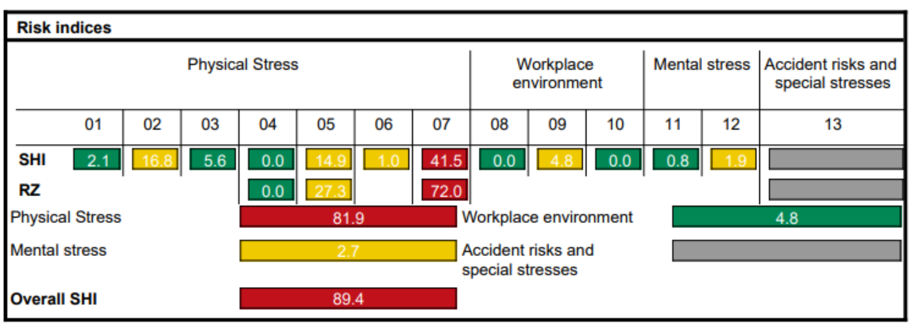


Figure 5. SERA results

(1) <u>Legs and Feet:</u>
Walking to retrieve the parts lead to leg and foot fatigue, especially since the distance was substantial and the workers needed to make frequent trips throughout the shift. Risks associated with these constant motions include tripping and falling.

(2) <u>Back and Spine:</u>
The workers were required to carry parts back to their workstation, potentially placing additional strain on the back and spine. Since the walking is prolonged and done simultaneously with a load, it strains the back and spine which can potentially lead to musculoskeletal issues.

(3) <u>Shoulders and Arms:</u>
Carrying the parts back to the workstation, which are awkwardly shaped, strains the shoulders, arms, and wrists.

(4) Hands and Fingers:
When workers needed to pick up these parts during the walk, it required frequent gripping and handling, which lead to hand and finger fatigue and or even repetitive strain injuries hence flagged as red on SERA.

The safety & ergonomics risk assessment of the manual separation of parts revealed the potential impact on the following various body parts:

(5) Hands and Fingers:
Manual separation often involves grasping, pinching, or twisting parts, which strain the fingers and hands. This can potentially lead to risk of repetitive strain injuries (RSIs) like carpal tunnel syndrome, tendonitis, or trigger finger.

(6) Shoulders:

Workers are required to lift, reach, or extend their arms to separate these tightly attached batch of parts, which strain the shoulders.

(7) Back:

Bending, twisting, or awkward postures during part separation affects the lower back hence figure 5 indicate red on that area.

5.6 Proposed Improvements

To address the issue of inadequate ergonomic workstation layout, facility layout design should be undertaken by the company to improve the flow of the work, thereby ensuring that the components required for production are within easy reach for the workers. Companies may reduce the physical strain on workers by providing them with ergonomically built workstations and employing suitable work procedures, enabling them to maintain greater levels of performance throughout the day to consistently meet their daily output requirements.

A systematic approach is recommended to address the lack of tools for efficient separation of tightly packed sub-parts. It is crucial to identify the specific sub-parts that are tightly packed and understand the specific challenges associated with separating them, such as size, material, or packaging. Based on the specific challenges, the types of tools needed should be identified and acquired or check if any existing tools can be adapted or repurposed for this task. The tool(s) should be ergonomically designed to minimize strain on workers, reduce cycle time and assist to achieve daily volume.

Data recording and analysis play a fundamental role in monitoring progress. Therefore, records of cycle times, changes in cycle time, shifts in productivity, and downtime related to part separation should be kept and this data can and should be used for ongoing analysis to identify areas for improvement.

6. Conclusion

The primary goal of this research was to address the critical challenge of the front-end wheelhouse stations at a South African automotive company’s inability to meet cycle time and the target output requirements. This research has been characterized by a methodical investigation involving several key phases. Initially, an extensive review of relevant literature was undertaken to gain a comprehensive understanding of the existing knowledge and best practices in the field of ergonomics and workplace productivity. Subsequently, a well-structured research methodology was formulated, guided by the research onion, so as to systematically investigate and address the identified issue.

The empirical analysis of data collected directly from the front-end wheelhouse stations played a central role in this research. It involved collecting and analysing real-world data and making observations to draw meaningful conclusions. Through the analysis of the data and a comprehensive evaluation of the workstations' ergonomics, it became evident that the existing ergonomic setups were the primary contributors to the delayed cycle times hence affecting productivity in the organisation. When the ergonomics were further broken down into specific issues, it was discovered that the workers were facing difficulties when it came to segregating a group of identical parts due to their tightly packed nature. Moreover, the workers encountered issues relating to excessive movements, primarily caused by the distant placement of these parts from their workstations. Additionally, they were required to individually collect these parts as per the specific instructions outlined within the standard operating procedures.

Better tooling and facility layout design were recommended to improve the cycle time of sub-parts that are tightly packed. These recommendations represent a concrete roadmap for addressing the identified issues and implementing strategic ergonomics interventions that can lead to improved workplace productivity and, consequently, higher daily production outputs at the company.

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Biography

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Annexure A

Survey 1:Front End Wheelhouse Survey

1. On average, how many vehicles are processed in the front wheelhouse station per hour?

- ☐ **Less than 10**
- ☐ **10-20**
- ☐ **21-30**
- ☐ **More than 30**

2. How often do you meet the cycle time goal?

- ☐ **Always**
- ☐ **Often**
- ☐ **Occasionally**
- ☐ **Rarely**
- ☐ **Never**

3. What is the cycle time goal for the front wheelhouse station (in seconds)?

- **…………………………………………..……….**

5. How would you rate the efficiency of the equipment and tools in the front wheelhouse station?

- ☐ **Very Efficient**
- ☐ **Efficient**

- **Neutral**
- **Inefficient**
- **Very Inefficient**

6. <u>Can you describe any specific challenges or issues you face in the front wheelhouse station that affect cycle time and output?</u>

- **…………………………………………………………**

7. <u>Have there been any recent changes or modifications to the front wheelhouse station or the production process that you believe have affected cycle time and output? If so, please describe.</u>

- **…………………………………………………………**

8. <u>In your opinion, what improvements or changes could be made to the front wheelhouse station to help achieve or exceed the cycle time goal?</u>

- **…………………………………………………………**

9. <u>Is there anything else you would like to add or any other comments you have regarding cycle time and output in the front wheelhouse station?</u>

- **…………………………………………………………..**

Annexure B

Survey 2: Front End Wheelhouse Survey
1. On a scale of 1 to 5, how comfortable is your workstation in terms of ergonomics? ☐ Very uncomfortable ☐ Uncomfortable ☐ Neither comfortable or uncomfortable ☐ Comfortable ☐ Very comfortable ***2. Do you have access to ergonomic tools and equipment in your workplace?*** ☐ Yes ☐ **No** ***If yes, please list the ergonomic tools or equipment you have access to.*** • ……………………………………………………… ***3. How often do you experience difficulties or delays in reaching your cycle time due to ergonomic issues?*** ☐ Frequently, ☐ Occasionally ☐ Rarely ☐ **Never**

4. On a scale of 1 to 5, how satisfied are you with the current ergonomics of your workstation?

- ☐ Very Dissatisfied
- ☐ Dissatisfied
- ☐ Neither satisfied or dissatisfied
- ☐ Satisfied
- ☐ Very Satisfied

5. Please describe specific ergonomic challenges that have caused delays in reaching your cycle time

- **………………………………………………………..**
- **……………………………………………………….**

6. Have any ergonomic interventions or improvements been implemented in your workspace recently?

- ☐ Yes
- ☐ No

If yes, please describe the ergonomic interventions and their impact on your cycle time.

- **…………………………………………………………………..**

7. Overall, how do you think ergonomics influences your productivity?

- ☐ Positively

- ☐ Negatively
- ☐ No Significant Influence

8. <u>What suggestions do you have for further improving ergonomics in your work environment to enhance productivity?</u>

- ***…………………………………………………………………………..***
- ***…………………………………………………………………………...***

9. <u>Please provide any additional comments or insights regarding the relationship between ergonomics and cycle time that you believe are important.</u>

- ***…………………………………………………………………………….***
- …………………………………………………………………………...