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RESEARCH ARTICLE

Ergonomic Improvements in Service and Manufacturing Sectors

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ABSTRACT

Numerous efforts to increase productivity in businesses have been made in every period on a global scale. At this point, the concept of ergonomics comes to the forefront. Ergonomics is a sort of workplace design that maximizes efficiency and productivity while minimizing discomfort. During ergonomic studies, people's movements while working in the sector and the location of the equipment they use are examined to determine whether they are appropriate for the efficient and healthy operation of the human body. These examinations are conducted with a range of tools and equipment. Multi-criteria Decision Making (MCDM) is used in this research. The research findings are examined and analyzed in accordance with ergonomic standards, and task efficiency is measured. The use of ergonomic tools and equipment, coupled with ergonomic training, emerged as vital strategies to mitigate risks and enhance operational efficiency. Moreover, the time study conducted in the milk production process demonstrated a clear correlation between extended break times and improved worker efficiency, underscoring the importance of ergonomic considerations in scheduling and workload management.

Keywords: Efficiency, Service and Manufacturing Sectors, Ergonomic Standards

1. Introduction

Ergonomics is the study of creating a workplace to satisfy the demands of people, with the goal of increasing efficiency, productivity, and decreasing discomfort. It entails adapting instruments to the demands of the user and emphasizing correct posture to reduce the impact of repetitive movements. The modern workplace's usage of computers and fast evolving technology has raised the need for ergonomics, with desks, chairs, displays, keyboards, and lighting all requiring evaluation. Ergonomics also takes into account the requirement for movement throughout the day, with traditional workplace furniture encouraging stiff postures and little movement. Sedentary office behavior can be combated by striking a balance between sitting and standing, facilitated with height-adjustable desks.

This article delves into the critical role of ergonomic improvements in enhancing workplace efficiency and promoting health in both service and manufacturing industries. Within the study, Ergonomic Improvements in Service and Manufacturing Sectors are examined. Because of that, this study examines findings from selected businesses, analyzing their ergonomic standards and measuring task efficiency. When reviewing the literature, one can see various studies and findings related to ergonomic improvements specifically within the service and manufacturing sectors. Ergonomic improvements have become increasingly essential in service and manufacturing sectors due to their potential impact on worker health, productivity, and overall organizational performance. According to previous study conducted by Dul et al. (2012), ergonomic interventions in these sectors aim to mitigate work-related musculoskeletal disorders (MSDs) and improve job satisfaction by aligning tasks, tools, and environments with human capabilities and limitations. On the other hand, Bernard et al. (2009)'s study highlights that manufacturing and service industries often face challenges related to MSDs due to repetitive tasks, awkward postures, and heavy lifting. Ergonomic improvements such as proper workstation design, use of ergonomic tools (e.g., adjustable chairs, lifting aids), and training in ergonomic practices are crucial in reducing the prevalence of MSDs.

Within the scope of literature review, ergonomic improvements in service and manufacturing sectors are vital for enhancing workplace safety, productivity, and employee well-being. The integration of ergonomic principles not only reduces the risk

of work-related injuries and musculoskeletal disorders but also fosters a positive work environment conducive to long-term organizational success.

In the context of the article; In the second part, explanation of ergonomics and effects of ergonomic factors on efficiency are examined in detail, In the third part, ergonomic study in production and service sectors are mentioned. Methodology is explained in the fourth part. Finally discussion, evaluation and conclusion are given in the fifth and sixth part.

2. Explaining Ergonomics And Effects Of Ergonomic Factors On Efficiency

2.1 What is Ergonomics?

Ergonomics encompasses various elements such as adjusting furniture to fit user needs, promoting proper posture, and optimizing tools like tables, chairs, screens, keyboards, and lighting. These adjustments are crucial as they contribute to a healthy work environment by encouraging regular movement and supporting correct posture among employees. In industries experiencing rising labor demands, such as manufacturing and services, ergonomic studies are indispensable.

During ergonomic assessments, the movements of individuals while performing tasks (such as carrying, tugging, lifting, and pushing) are meticulously observed. Additionally, the placement of equipment is evaluated to ensure it facilitates efficient and healthy operation of the human body (Perera et al. 2024). Various tools and equipment are employed during these assessments, including:

- Hand, Back, and Leg Dynamometers: Measure muscle strength and assess stress on different body parts.
- Noise and Sound Meters: Evaluate noise levels to mitigate potential hearing damage.
- Temperature and Humidity Measuring Devices: Ensure optimal working conditions for comfort and health.
- Bending Angle Measuring Set: Assess posture and ergonomic alignment during tasks.
- Light Intensity Meter: Optimize lighting to reduce eye strain and enhance visibility.

These tests and measurements are critical in determining the safety and suitability of work activities for the human body, identifying potential risks, and proposing effective solutions.

Once recommendations for ergonomic improvements are formulated based on assessment findings, the implementation phase commences. This phase involves integrating ergonomic solutions into the workplace to enhance efficiency, promote employee health, and optimize task performance (Rodriguez et al. 2022). Solutions may include:

- Adjusting Workstation Layouts: Rearranging desks, chairs, and monitors to promote proper posture and reduce strain.
- Providing Ergonomic Tools: Supplying adjustable chairs, ergonomic keyboards, and height-adjustable desks to accommodate varying user needs.
- Training Programs: Conducting workshops and training sessions to educate employees on proper ergonomic practices and techniques.
- Continuous Monitoring and Evaluation: Regularly assessing the effectiveness of ergonomic interventions and making adjustments as needed to maintain optimal working conditions.

2.2. Effects Of Ergonomic Factors On Efficiency

While putting people first has a good impact on productivity, it has also enhanced the relevance of "ergonomics," an area of research that allows employees to work more comfortably, with less weariness, and with less risk of work accidents and occupational diseases.

Ergonomics, as it is known, is a working discipline that aims to increase system efficiency, ensure human-machine-environment harmony, and humanize work in the industrial work environment (Hendrick, 2000).

Businesses share common goals such as producing higher-quality goods and services than competitors, becoming the sector's technological leader, consistently increasing sales volume and profitability, preventing waste by reducing expenses, increasing employee motivation, and strengthening the company's image.

Productivity growth is the primary source of economic progress in all countries, developed or developing, that adopt free market economies or central planning.

Ergonomic considerations, among other things, have a significant impact on raising or decreasing labor productivity. Physical variables such as working environment and location, sound, lighting, and environmental temperature are critical for employees to work healthier, safer, and more productively (Sinno and Ammoun, 2019).

Generally, according to the researches conducted globally, one can say easily that ergonomic working environments have a favorable impact on employee productivity and work performance.

In a field research carried out to boost employee productivity, Shikdar and Biman (2003) discovered that the ergonomic working environment is at least as significant to employees as economic instruments such as wage increases.

On the other side, Wachter and Yorio (2014) emphasizes that ergonomic interventions not only enhance worker safety and comfort but also optimize task performance and productivity. For instance, optimizing workflow layouts and implementing ergonomic equipment can streamline processes and minimize downtime associated with injuries or discomfort.

In relation to the topic, the impact of ergonomic improvements on employee health and well-being is well-documented. According to Choobineh et al. (2006), ergonomic adjustments such as proper seating arrangements, ergonomic keyboards, and adequate lighting contribute to reducing physical strain, fatigue, and stress among workers, thereby improving overall job satisfaction and reducing turnover rates.

Ergonomic assessments in service and manufacturing sectors involve a variety of tools and methodologies to evaluate workplace conditions and identify areas for improvement: Tools like dynamometers and anthropometric kits are used to measure muscle strength, joint angles, and reach capabilities, helping to assess ergonomic risks associated with specific tasks (Smith et al., 2016).

In this sense, Kant et al. (2015) indicates that instruments such as noise meters, temperature gauges, and lighting meters are employed to evaluate environmental factors that can impact worker comfort and performance (Kant et al., 2015).

Similarly, Hinett (2013) states that techniques such as task analysis and ergonomic job analysis are used to evaluate task demands and optimize workstation layouts to minimize ergonomic risk factors.

From another perspective, Rivilis et al., (2008) indicates that successful implementation of ergonomic interventions involves collaborative efforts between employers, employees, and ergonomic specialists. Effective strategies include education and training. Providing comprehensive training programs on ergonomic principles and safe work practices enhances awareness and compliance among workers

In another study conducted by Hendrick and Kleiner (2001) on this subject, the following results were reached: Regular evaluation and adjustment of ergonomic interventions based on feedback and evolving workplace conditions ensure sustained benefits in terms of safety, productivity, and employee satisfaction.

Employees and Employers adopting ergonomics principles in both manufacturing and service sectors provides multifaceted benefits to organizations and the workforce. The main benefits that can be realized with a proactive approach to ergonomic design are improved health and safety, increased productivity, increased job satisfaction, reducing absence, cost savings and increased employee participation (Garner et al. 2023).

The model developed by Deros et al. (2016) named Ergonomics Model Approach In Optimizing of Work is shown in Figure 1.

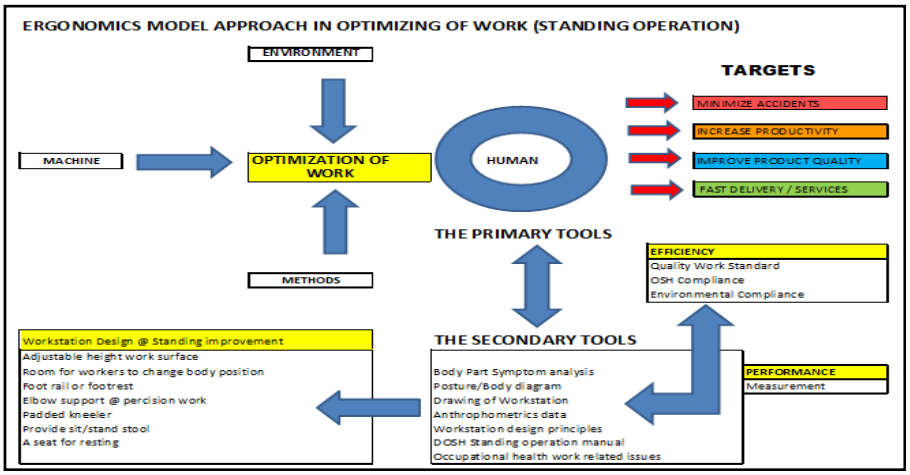

Figure 1. Ergonomics Model Approach In Optimizing of Work (Deros et al., 2016)

In a nutshell, ergonomic factors optimize the work environment, increase productivity, reduce fatigue, and prevent workplace accidents. Properly applying these factors also enhances employee motivation and overall job satisfaction. The contribution of ergonomic factors to efficiency can be seen in physical comfort, fatigue reduction, accident prevention, psychological effects, workflow and productivity and long-term health issues.

3. Ergonomics Study in Production and Service Sectors

Ergonomics is a discipline that primarily shapes working conditions. It plays an important role in both the manufacturing sector and the service sector.

According to Moore (2018) the heart of manufacturing success lies in the well-being of its workforce. Investigating ergonomic practices in assembly line setups with a focus on improving worker comfort, safety, and overall performance becomes imperative.

Wang et al. (2019) stated that the future of manufacturing lies in the synergy between human skills and robotic precision. Reviewing literature on the integration of robotics in manufacturing processes and analyzing how collaborative robots can be designed to enhance both productivity and ergonomic conditions for human workers will be useful.

The quality of patient care is inseparable from the ergonomics of the care providers (Standley and Vega, 2019). Exploring the ergonomic considerations in patient care areas, including nurse stations, examination rooms, and patient handling techniques, with a focus on improving healthcare professionals' well-being and patient outcomes is improtant for health system.

Well-designed medical equipment is the silent partner of every healthcare professional (Martin et al. 2008). Analyzing literature regarding the ergonomic design of medical equipment, such as diagnostic tools and patient beds, becomes crucial for enhancing usability and reducing the risk of musculoskeletal disorders among healthcare practitioners.

According to Al-Romeedy et al. (2023); first impressions in hospitality are made at the ergonomic frontline. Investigating ergonomic considerations at the front desks of hotels and service establishments becomes essential, evaluating the impact on employee performance, customer satisfaction, and overall service quality.

Prolonged sitting is a common enemy across sectors (Gilson et al., 2011). Conducting a comprehensive comparative analysis of the impact of prolonged sitting on employees across various sectors becomes imperative. Associated health risks and propose strategies for promoting movement and physical activity in the workplace will be examined.

Psychosocial factors are silent influencers of workplace well-being (Li & Olynic, 2020). Exploring the role of psychosocial factors, including job stress, in contributing to ergonomic challenges becomes essential. The impact of organizational culture, leadership styles, and interpersonal relationships on employee well-being will be analyzed.

Digitalization should enhance, not hinder, workplace well-being (Mumtaz et al., 2023). Investigating the ergonomic challenges posed by increased digitalization becomes crucial, including the use of computers, tablets, and smartphones. This section will examine studies on the potential health risks associated with prolonged digital device use and propose ergonomic solutions.

Wearable devices should empower, not encumber, professional performance (Stefana et al., 2021). Analyzing the ergonomic implications of wearable devices, such as smartwatches and fitness trackers, in professional environments becomes crucial. Here are some basic principles of how ergonomics is applied in both sectors:

3.1 Manufacturing (Production) Sector:

Workstations should be ergonomically designed to enable workers to work comfortably and effectively. Tables, chairs, tools and equipment should be arranged taking into account the worker's body mechanics. Tools and equipment used in production should be designed to be compatible with the body structure of workers. Factors such as repetitive movements and weight that may occur during the use of vehicles should be taken into account. Workers should be trained in subjects such as correct body mechanics and lifting techniques, thus contributing to the prevention of possible injuries (International Labour Office, 2010).

3.2 Service industry:

Office furniture and computer equipment should be designed to enable employees to work comfortably for long hours. Factors such as table heights and chair support features are important. Positions that directly interact with employees in the service industry should be ergonomically designed to increase customer satisfaction and ensure employee comfort. For example, it should be considered that a dreary work environment can negatively impact customer interaction. Workers in the service industry should use ergonomically designed tools and equipment when performing their daily tasks. This can improve work efficiency and prevent musculoskeletal problems (Koirala and Nepal, 2022).

4. Methodology

The purpose of the research conducted is to determine whether the working environment in business life is compatible with human body health and standards, and to plan and implement improvements that can be made in this case. In this way, the goal is to ensure that the work is efficient. In the production and service sectors, intensive labor force, working environments, and equipment that are not suitable for the human body harm the health of employees and, consequently, reduce productivity in business life. Due to this situation, sub-problems such as insufficient workload, dismissal of unproductive employees, and

adaptation issues for new employees are experienced. In the context of the study assumptions, observations and surveys indicate that workers in the manufacturing, healthcare (hospital) and education (school) sectors face similar ergonomic problems (Edem et al. 2017). This assumption can increase the shareability of solution proposals across sectors.

Employees' awareness and training levels on ergonomic issues may vary between sectors. For this reason, it is important that the solution suggestions to be developed are sector-specific and in line with the awareness of the employees. It is believed that ergonomic regulations, improving working conditions and making them compatible with ergonomic standards have an efficiency-increasing effect. This assumption can provide a benchmark to evaluate whether the study is successful or not. The solution suggestions will be applicable. This is about solutions where the proposed ergonomic regulations can be easily implemented, considering cost, time and resource constraints. Cooperation between employer and employee is of critical importance for ergonomic studies to be successful. This cooperation can be achieved in relevant sectors. Ergonomic improvements will increase employee satisfaction and therefore positively affect business performance (Jilcha, 2024).

Within limitations; the number of samples selected from certain sectors may be limited. This may require caution in making generalizations and may limit how well findings translate to a general population. Employees' awareness of ergonomic issues may influence their responses. This may result in the data obtained not fully reflecting the actual situation. There may be different job structures and requirements among employees in each industry. Therefore, it can be difficult to determine whether the solutions developed are equally suitable for all sectors. There may be technological and financial constraints that may limit the feasibility of the study. In particular, evaluating the feasibility and cost-effectiveness of proposed ergonomic solutions may require struggling with limited resources. The project may need to be completed within a certain period of time, which may limit the exploration of more comprehensive, long-term solutions. Dependent variables, such as employee satisfaction and productivity, can be affected by many factors, and it can be difficult to control all of these factors. Ergonomic issues often rely on subjective evaluations. This means that the data obtained may sometimes be based on personal judgment. External factors such as social, economic or political changes can affect workers' ergonomic experiences and it may not be possible to control these factors.

This research investigates the physical difficulties people face in business life, searches for solutions to these problems, plans and tries the solutions it finds. If the experiment is successful, it reveals solution ideas that will enable people to work in a more productive environment. Research is important for protecting human health and improving productivity. The research question addressed in this paper is defined as

1. How can the importance of productivity from an ergonomic perspective be understood within the work environment?
2. What are the factors that affect productivity?

The methodology outlined below has been applied to find answers to these questions. By visiting the production and service sectors determined in the research, the problems encountered in the relevant sector have been identified. Possible additional problems have also been identified by conducting a survey with people working in the sector. The primary materials used in the research are a camera, sound measuring device, and temperature measuring device. The difficulties people face while working have been identified. A sound measuring device has been used to gather data about the noise level of the working environment. The temperature and humidity measuring device provides information about the temperature and humidity of the working environment. Tools such as meters, protractors, and rulers have been used to measure numerical data (angle, height, etc.). Simple measuring tools have been used in the research.

According to the information obtained, many studies have been carried out in the field of ergonomics. In this context, hospitals can be example of the work done in the service sector. Hospitals are a complex place where many people work together. Due to density, high noise, airless environment and inadequate application areas compared to the number of people working reduce work efficiency. Similarly, factories can be example of the production sector. It is difficult for many people to work together. People work in physically heavy jobs. Working standing for long periods of time or lifting heavy items is harmful to the human body. In addition, high noise caused by machines and excessively hot and extremely cold environments depending on the product harm people's physical health.

The most appropriate method for this research has been determined as going to the place where the research will be conducted and making direct observations. The observations have been recorded with photographs or videos. In addition, previously determined measurements such as noise, light intensity, and bending angle have been re-measured and noted, and solutions have been considered accordingly.

Multi-criteria Decision Making (MCDM) is used in this research. MCDM is a sub-discipline of operations research that evaluates multiple conflicting criteria in decision-making, including in daily life, business, government, and medicine. Conflicting criteria include cost or price, quality, and customer satisfaction. In daily life, people often weigh multiple criteria implicitly, but when stakes are high, it is important to structure the problem and explicitly evaluate multiple criteria. For example, in making a nuclear power plant decision, complex issues involving multiple criteria and multiple parties are deeply affected. Structuring complex problems well and considering multiple criteria explicitly leads to more informed and better decisions. Advances in MCDM since the early 1960s have led to the development of various approaches and methods, many

implemented by specialized decision-making software, for applications in various disciplines, including politics, business, environment, and energy.

Another tool used for analyzing is SPSS program. SPSS is a widely used statistical analysis program in social science, used by researchers from various fields such as market research, health research, survey companies, government, education research, marketing organizations, and data miners.

4.1 Analysis and results

Ergonomic disadvantages can affect worker health, safety and performance in production and service sectors. Ergonomics is the science of adapting human physiological and psychological characteristics to work environments. Therefore, ergonomic negativities can affect the performance of both workers and workplaces in the context of worker health and safety, loss of productivity, error and quality problems, employee dissatisfaction and quit rate and costs. As a result, ergonomic problems can bring additional costs to workplaces (Markova and Skurkova, 2023). These negative effects can lead to a decrease in productivity in businesses. The analyses conducted in this article are aimed at identifying these negative situations and providing solutions as a result.

4.2 Factory (production) Analysis

In the context of the research a factory that produces meat and milk as a production sector is examined. The first qualitative observation being encountered in milk production was the extremely high temperature and extremely low temperature environments felt in various sections. For this reason, firstly the temperature measurement of the environment is observed. In general, the recommended working environment temperature for jobs requiring muscular effort is between 20 and 24°C. This range ensures that employees feel comfortable and can maximize their performance. However, this temperature range may not be equally suitable for everyone. Some people may be more productive in colder or warmer environments, so the temperature in the work environment should be set within a preferred or appropriate range. The temperature measured in the packaging section is 18 degrees Celsius. Normally, this temperature is slightly below the reference value, but as a result of the short survey in the packaging department, no problem was identified for this situation.

The temperature of the cheese melting section, which is another temperature observation point, was measured. The temperature of the working environment was measured as 30 degrees Celsius. The range is above the reference level. According to this research, working at high temperatures for a long time primarily causes heart and circulatory system problems. Another observation area is the cheese melting pot. A temperature of 65-77 degrees is required for cheese melting. During this melting process, a worker must constantly monitor it. The person performing the control works in shifts for 4 hours. While working, he works on a 3 meter high ladder. According to research, working at very high temperatures causes dehydration (excessive fluid loss in the body). As a result of this situation, sudden dizziness and fainting may occur. Both working at high temperatures and working at high levels increase the possibility of occupational accidents.

On the other hand, working conditions were at very low temperatures in the meat production department. Especially the packaging and cutting sections were measured at 0 and 4 degrees Celsius. This situation is not sufficient for human health. The factory provides appropriate clothing for this type of working environment.

However, as a result of interview with the workers, they stated that they could not sleep all the time because working in such clothes caused limited movements. Likewise, we believe that working at low temperatures is not suitable for human health. According to research, working at low temperatures increases the risk of hypothermia, and can cause vascular injuries, distraction, and facial paralysis, especially when the face is exposed to cold for a long time. there was also no protection for the face.

During the observations, it is noticed that work was carried out on wet ground from time to time. Shoes are actually worn for such occasions. Maybe the quality of the shoes can be improved.

4.2.1 Increasing Efficiency and Reducing Fatigue With Time Study Calculations

The milk production process examined at a factory. The workers at this factory operate from 8:00 am to 5:00 pm, with only a 30-minute break within this timeframe. This short break might not be sufficient for optimal worker performance. Therefore, how increasing break times would affect the efficiency of the workers is being investigated.

To study this, the time taken by five workers to complete a specific task is measured: packaging small 330 ml milk bottles into boxes of 50 each. On the first day, with a 30-minute break, the workers' performance was as follows:

Worker 1: Packed 50 boxes in 23 minutes in the morning and 28 minutes in the afternoon.

Worker 2: Packed 50 boxes in 20 minutes in the morning and 26 minutes in the afternoon.

Worker 3: Packed 50 boxes in 22 minutes in the morning and 27 minutes in the afternoon.

Worker 4: Packed 50 boxes in 20 minutes in the morning and 26 minutes in the afternoon.

Worker 5: Packed 50 boxes in 22 minutes in the morning and 28 minutes in the afternoon.

On the second day, the break time was increased to 90 minutes. The workers' performance was measured again:

Worker 1: Packed 50 boxes in 21 minutes in the morning and 22 minutes in the afternoon.

Worker 2: Packed 50 boxes in 21 minutes in the morning and 21 minutes in the afternoon.

Worker 3: Packed 50 boxes in 23 minutes in the morning and 21 minutes in the afternoon.

Worker 4: Packed 50 boxes in 20 minutes in the morning and 22.5 minutes in the afternoon.

Worker 5: Packed 50 boxes in 21 minutes in the morning and 22 minutes in the afternoon.

4.2.2 Analysis

Average Packaging Times

- Day 1 (30-minute break): The average time to pack 50 boxes was 24.2 minutes.
- Day 2 (90-minute break): The average time to pack 50 boxes was 21.45 minutes.

In industrial engineering and time study, the following formulas are commonly used to calculate efficiency improvement and fatigue reduction. Efficiency improvement measures the change in performance over time, typically expressed as a percentage (Indeed, 2024). Efficiency improvement (%) equation is shown at Equation 1.

Formula:

$$\text{Efficiency Improvement } (\%) = \left(\frac{\text{Initial Performance Time} - \text{Improved Performance Time}}{\text{Initial Performance Time}}\right) \times 100 \quad (1)$$

Fatigue can be analyzed by comparing the performance degradation over a working period. A common approach is to calculate the difference in performance between the morning and the afternoon sessions (EN380 Naval Materials). Fatigue calculation formula is shown at Equation 2.

Fatigue Calculation:

$$\text{Fatigue (Day)} = \frac{\sum(\text{Afternoon Time} - \text{Morning Time})}{\text{Number of Workers}} \quad (2)$$

Table 1. Day 1 Data (30-minute break)

Worker No	Morning (min)	Afternoon (min)	Average (min)
1	23	28	$\frac{23+28}{2} = 25.5$
2	20	26	$\frac{20+26}{2} = 23.0$
3	22	27	$\frac{22+27}{2} = 24.5$
4	20	26	$\frac{20+26}{2} = 23.0$
5	22	28	$\frac{22+28}{2} = 25.0$

Table 2. Day 2 Data (90-minute break)

Worker No	Morning (min)	Afternoon (min)	Average (min)
1	21	22	$\frac{21+22}{2} = 21.5$
2	21	21	$\frac{21+21}{2} = 21.0$
3	23	21	$\frac{23+21}{2} = 22.0$
4	20	22.5	$\frac{20+22.5}{2} = 21.25$
5	21	22	$\frac{21+22}{2} = 21.5$

CalculatingAverage Packaging Times for Day 1 and Day 2

Day 1 Average:

$$\frac{25.5+23.0+24.5+23.0+25.0}{5} = \frac{121.0}{5} = 24.2 \text{ minutes}$$

Day 2 Average:

$$\frac{21.5+21.0+22.0+21.25+21.5}{5} = \frac{107.25}{5} = 21.45 \text{ minutes}$$

Calculating Efficiency Improvement

$$\text{Efficiency Improvement } (\%) = \left(\frac{\text{Day 1 Average} - \text{Day 2 Average}}{\text{Day 1 Average}}\right) \times 100$$

Substitute the averages calculated:

$$\text{Efficiency Improvement } (\%) = \left(\frac{24.2-21.45}{24.2}\right) \times 100 \approx 11.36\%$$

Calculate Fatigue Reduction

Day 1 Fatigue (Average difference between morning and afternoon times)

$$\text{Day 1 Fatigue} = \frac{(28-23)+(26-20)+(27-22)+(26-20)+(28-22)}{5} = \frac{5+6+5+6+6}{5} = 5.6 \text{ minutes}$$

Day 2 Fatigue (Average difference between morning and afternoon times)

$$\text{Day 2 Fatigue} = \frac{(22-21)+(21-21)+(23-21)+(22.5-20)+(22-21)}{5} = \frac{1+0+2+2.5+1}{5} = 1.3 \text{ minutes}$$

4.2.3 Summary Tables

Table 3. Day 1 Data

Worker No	Morning (min)	Afternoon (min)	Average (min)
1	23	28	25.5
2	20	26	23.0
3	22	27	24.5
4	20	26	23.0
5	22	28	25.0
Average	**21.4**	**27.0**	**24.2**

Table 4. Day 2 Data

Worker No	Morning (min)	Afternoon (min)	Average (min)
1	21	22	21.5
2	21	21	21.0
3	23	21	22.0
4	20	22.5	21.25
5	21	22	21.5
Average	**21.2**	**21.7**	**21.45**

Table 5. Efficiency Improvement

Metric	Value
Day 1 Average (min)	24.2
Day 2 Average (min)	21.45
Efficiency Improvement (%)	11.36%

Table 6. Fatigue Reduction

Metric	Value
Day 1 Fatigue (min)	5.6
Day 2 Fatigue (min)	1.3

4.2.4 Conclusion

Efficiency Improvement: The average packaging time decreased from 24.2 minutes to 21.45 minutes, resulting in an efficiency improvement of approximately 11.36%.

Fatigue Reduction: The average difference between morning and afternoon packaging times decreased from 5.6 minutes to 1.3 minutes, indicating a reduction in fatigue.

These results show that increasing the break time from 30 minutes to 90 minutes significantly improved worker efficiency and reduced fatigue.

4.3 Service (Hospital) Analysis

Investigations in hospitals are conducted in pediatric outpatient clinics and emergency triage sections.

The situation observed in the pediatric outpatient clinics focused on optimizing the balance between the number of doctors available and the patient load each doctor could effectively manage. With 4 doctors on staff, the daily patient count varied significantly, ranging from a minimum of 30 to a maximum of 80 patients per doctor. As the day progressed, there was a noticeable decline in each doctor's performance, suggesting the need for interventions to enhance their efficiency and overall clinic productivity.

A comprehensive analysis has been conducted to address these challenges and explore potential strategies aimed at increasing doctors' working performance while maintaining high-quality patient care. A key consideration was the seasonal impact, particularly during the spring months when patient volumes tended to peak, often reaching the upper limits of what the current staffing could handle effectively.

Efficiency calculations were crucial in the assessment. By evaluating the average time each doctor spent per patient and factoring in breaks, administrative tasks, and patient wait times, opportunities were identified for improvement. For instance, the patient throughput rate per doctor-hour was measured, which helped quantify the actual capacity utilization versus the theoretical maximum. This analysis highlighted moments of peak congestion and inefficiencies during the day.

Based on these findings, a strategic plan was developed to optimize clinic operations. One approach involved adjusting the patient scheduling system to spread out appointments more evenly throughout the day, thereby reducing bottlenecks and minimizing wait times. Additionally, introducing a staggered lunch break schedule ensured continuous coverage and maintained service levels during peak hours.

Recognizing the need for additional manpower during high-demand periods, such as spring, we proposed increasing the number of doctors available on duty. By hiring supplementary staff or utilizing part-time physicians during peak seasons, we aimed to alleviate workload pressures on existing doctors and maintain consistent service quality throughout the day.

Quality assurance measures were also integrated into the plan. Regular performance evaluations and feedback mechanisms were implemented to monitor and improve clinical outcomes, patient satisfaction levels, and overall operational efficiency. By fostering a culture of continuous improvement and learning, ıt was aimed to enhance both the patient experience and the working environment for healthcare providers.

In conclusion, the initiative to optimize the pediatric outpatient clinic's performance involved a multifaceted approach combining strategic staffing adjustments, efficiency calculations, and quality assurance measures. By aligning staffing levels more closely with patient demand and implementing targeted operational improvements, it was aimed to achieve sustainable enhancements in both clinical productivity and patient care outcomes.

4.4 Efficiency Calculations In The Hospital (Clinics and Emergency Department)

4.4.1 Clinics

To further understand the optimization process for the pediatric outpatient clinic, let's dig deeper into the calculations and present a more thorough analysis complete with formulas and figures:

To determine the patient throughput rate per doctor-hour, it is being calculated as shown at Equation 3.

$$\text{Throughput Rate} = \frac{\text{Total Patients Seen}}{\text{Total Doctor-hours}} \tag{3}$$

Where:

- Total Patients Seen: Sum of patients seen by all doctors in a day.
- Total Doctor-hours: Sum of hours worked by all doctors in a day.

For example, if:

- Doctor A sees 70 patients in 8 hours,
- Doctor B sees 60 patients in 7 hours,
- Doctor C sees 75 patients in 8.5 hours,
- Doctor D sees 65 patients in 7.5 hours,

Then:

- Total Patients Seen = 70 + 60 + 75 + 65 = 270 patients
- Total Doctor-hours = 8 + 7 + 8.5 + 7.5 = 31 hours

$$\text{Throughput Rate} = \frac{270}{31} \approx 8.71 \text{ patients per doctor-hour}$$

To calculate the average time each doctor spends per patient, the formula is used shown at Equation 4.

$$\text{Average Time per Patient} = \frac{\text{Total Doctor-hours} \times 60}{\text{Total Patients Seen}} \tag{4}$$

Where:

- Total Doctor-hours: Sum of hours worked by all doctors in a day (converted to minutes for consistency).

Using the previous example:

- Total Doctor-hours = 31 hours = 1860 minutes
- Total Patients Seen = 270 patients

$$\text{Average Time per Patient} = \frac{1860}{270} \approx 6{,}88 \quad \text{minutes per patient}$$

4.4.2 Proposed Staffing Adjustments: Current Staffing vs. Optimal Staffing

Based on the patient demand and efficiency calculations, it was determined that the current staffing level of 4 doctors might not suffice during peak periods, such as spring when patient volumes are high. The optimal staffing level can be determined using a formula considering the patient load and desired throughput rate (Nguwi, 2024) and it is shown at Equation 5.

$$\text{Optimal Staffing} = \frac{\text{Total Patients}}{\text{Target Throughput Rate} \times \text{Average Time per Patient}} \tag{5}$$

Where:

- Total Patients: Max. expected daily patient load (e.g., 320 patients/day during peak times).

- Target Throughput Rate: Desired patient throughput rate (e.g., 9 patients per doctor-hour).
- Average Time per Patient: Calculated average time each doctor spends per patient (e.g., 6.88 minutes).

Let's assume:

- Total Patients = 320 patients/day
- Target Throughput Rate = 9 patients per doctor-hour

$$\text{Optimal Staffing} = \frac{320}{9 \times \frac{24.67}{60}} \approx 5.5$$

Based on this calculation, it's recommended to have approximately 6 doctors available during peak periods to maintain optimal patient flow and minimize wait times.

4.4.3 Quality Assurance and Performance Monitoring

4.4.3.1 Performance Metrics and Feedback Mechanisms

To ensure quality care and operational efficiency, performance metrics such as patient satisfaction scores, wait times, and adherence to scheduling protocols should be regularly monitored. Feedback mechanisms, including patient surveys and staff evaluations, are crucial for identifying areas needing improvement and implementing corrective actions.

4.4.3.2 Continuous Improvement Initiatives

Implementing continuous improvement initiatives involves regular review of operational processes, staff training and development programs, technology upgrades to support scheduling and patient management, benchmarking against industry standards and best practices.

By integrating these calculations, tables, and strategic recommendations, the pediatric outpatient clinic can effectively optimize its operations, enhance doctor performance, and improve overall patient care delivery during both regular and peak demand periods. This holistic approach ensures sustainable improvements in clinic efficiency and patient satisfaction, ultimately benefiting both healthcare providers and patients alike.

4.5 Emergency Department

In this research in the emergency department, the number of doctors, employees and patients in the patient registration, red, yellow and green areas are compared. At least 100 and at most 250 patients were coming to the emergency room a day. These patients were registered according to their severity, but only 1-2 people were working in the patient admission area and they could not perform some patient analyzes properly because the work areas were very small.

In the red area, there were 1 or 2 doctors because patient registration was not frequent, and when this patient arrived, there was a need to transfer doctors from other polyclinics depending on the emergency, so we added a more experienced doctor to the red area so that there was always at least 1 person.

There were 2-3 doctors and 2 nurses in the yellow area. In this area, the problem was with the nurses. After the doctors made the checks, they assigned some tasks to the nurses, but since the nurses could not keep up, the work of the doctors was disrupted, so we thought of the solution here by transferring the number of nurses from the necessary departments according to the situation.

There were 4 doctors and 2 nurses in the green area, but the problem here was a different situation; the nurses could not catch up because there were too many doctors here. We calculated the problem here as reducing the number of doctors. We have determined that 3 doctors are sufficient and nurses can be transferred depending on the situation, but this is sufficient.

4.5.1. Current Situation Analysis

4.5.1.1 Red Area (Critical Care)

In the red area of the ER, where critical patients are handled, there were typically 1 or 2 doctors available due to less frequent patient registration. However, when critical patients arrived, doctors had to be transferred from other areas, causing potential delays and disruptions. To ensure consistent coverage, an additional experienced doctor was assigned to the red area, ensuring that there was always at least one doctor present to handle emergencies promptly.

4.5.1.2 Yellow Area (Intermediate Care)

The yellow area of the ER housed 2-3 doctors and 2 nurses. Here, doctors conducted initial assessments and then assigned tasks to nurses. However, the nurses struggled to keep up with the workload, impacting the efficiency of doctors and patient

care. To address this issue, a flexible staffing strategy was implemented, allowing nurses to be transferred from other departments as needed, ensuring adequate support during peak times.

4.5.1.3 Green Area (General Care)

In the green area, which handled less severe cases, there were 4 doctors and 2 nurses. Despite the higher doctor-to-patient ratio, nurses faced challenges in keeping up with tasks due to the larger number of doctors. To optimize operations, the doctor count was reduced to 3, aligning it more closely with patient demand. This adjustment aimed to balance workload and enhance nurse efficiency without compromising patient care.

4.5.2 Efficiency Calculations and Optimization

In order to optimize ER efficiency, several key calculations and strategies were employed:

Patient Throughput Rate Calculation:

- Determine the average patient throughput rate per area to ensure timely care delivery.
- Example: If the ER handles 200 patients/day across all areas, and operates for 10 hours/day, the throughput rate can be calculated as:

$$\text{Throughput Rate} = \frac{\text{Total Patients}}{\text{Total Hours}} = \frac{200}{10} = 20 \text{ patients per hour}$$

4.5.3 Optimal Staffing Adjustments:

- Calculate optimal staffing levels based on patient severity and historical data.
- Example: For the red area, where critical care is crucial, ensure at least 1 doctor per shift, supplemented by additional staff during peak hours.

4.5.4 Nurse-to-Doctor Ratio Adjustment

- Evaluate and adjust the nurse-to-doctor ratio to optimize workflow and task delegation.
- Example: In the yellow area, adjusting to 2 nurses per 3 doctors allows for better support and task management, preventing bottlenecks.

4.5.5 Strategic Solutions Implemented

4.5.5.1 Enhanced Staffing Flexibility

- Instituted a flexible staffing approach, allowing for nurse reassignments based on workload fluctuations across ER areas.
- Example: Nurses are transferred from less busy departments to the yellow area during peak periods, ensuring adequate support for patient care tasks.

4.5.5.2 Task Delegation Optimization

- Improved task delegation protocols between doctors and nurses to streamline workflow and enhance operational efficiency.
- Example: Clear protocols are established for nurses to handle routine tasks after initial assessments by doctors, ensuring smoother operations.

4.5.5.3 Continuous Monitoring and Adjustment

- Implemented a continuous monitoring system to track patient flow, staff performance, and resource utilization.
- Example: Regular reviews and adjustments are made based on real-time data to optimize ER operations and maintain high standards of patient care.

By implementing these strategies, the emergency room can effectively address the challenges identified in each area while enhancing overall efficiency and patient satisfaction. Continuous monitoring and adjustment ensure that staffing levels and operational protocols remain aligned with patient demand, fostering a responsive and high-performing ER environment. This approach not only improves workflow management but also supports staff morale and patient outcomes, making it a sustainable solution for optimizing emergency medical services.

5. Discussion And Evaluation

Improving ergonomics in hospitals and production factories is crucial for addressing the efficiency challenges prevalent in these sectors. Ergonomic enhancements aim to optimize work environments, minimize physical strain, and foster safer, more

productive workflows. Here are some suggestions about how these improvements can mitigate efficiency issues in both hospitals and production factories:

5.1 Hospitals (Service Sector)

Efficiency challenges in hospitals often stem from the physical demands placed on healthcare professionals and administrative staff:

- Patient Handling Equipment: Implementing ergonomic beds, lifts, and transfer aids reduces the physical strain on nurses and caregivers, enabling quicker and safer patient handling processes.

- Workstation Design: Ergonomic desks, chairs, and optimized lighting in administrative areas and nurse stations enhance staff comfort and reduce fatigue, thereby improving focus and efficiency in tasks.

- Medical Equipment Ergonomics: Designing medical devices with ergonomic considerations minimizes the effort required for healthcare providers during procedures, contributing to faster response times and enhanced patient care.

- Training and Protocols: Comprehensive training on ergonomic practices, including efficient patient handling techniques and ergonomic principles in daily tasks, ensures staff can perform optimally while minimizing the risk of injuries.

By integrating ergonomic improvements in hospitals, efficiency can be significantly enhanced through reduced physical strain on staff, streamlined workflows, and improved patient care outcomes. However, challenges such as initial investment costs and the need for consistent adherence to ergonomic guidelines across diverse hospital departments remain critical considerations.

5.2 Production Factory (Manufacturing Sector)

Efficiency challenges in production factories often arise from labor-intensive tasks and operational bottlenecks:

- Workstation Ergonomics: Adjustable workstations, ergonomic tools, and anti-fatigue mats optimize worker comfort and productivity by minimizing physical strain during repetitive assembly line tasks.

- Automation and Robotics: Incorporating ergonomic automation solutions reduces reliance on manual labor, streamlines production processes, and enhances overall output efficiency.

- PPE and Safety Gear: Ergonomically designed personal protective equipment, such as gloves and footwear, enhances worker comfort and safety, supporting sustained productivity and operational continuity.

- Training and Rotation: Providing ergonomic training and implementing job rotation schedules ensures that workers maintain optimal performance levels while mitigating the risk of musculoskeletal disorders (MSDs) over time.

Ergonomic improvements in production factories can effectively address efficiency challenges by improving worker well-being, reducing downtime due to injuries, and increasing overall production output. Despite the initial investment costs, the long-term benefits in terms of enhanced efficiency and reduced operational disruptions justify these ergonomic interventions.

Efficiency challenges in hospitals and production factories can be effectively addressed through strategic ergonomic improvements. By prioritizing ergonomic design, equipment, and training initiatives, organizations can mitigate physical strain on workers, optimize workflows, and ultimately improve overall operational efficiency. Continued innovation and adaptation of ergonomic practices are essential for sustaining these improvements and meeting the evolving demands of both sectors. Investing in ergonomic solutions not only supports workforce health and well-being but also drives significant improvements in productivity and quality of outputs, making it a worthwhile endeavor for any organization aiming to enhance operational efficiency.

6. Conclusion

Some rearrangements can be done based on the findings of the calculations and hypotheses regarding this research. However, a concise description is provided below:

In conclusion, the comprehensive exploration of ergonomic challenges and efficiency optimizations in both manufacturing (production) and service (hospital) sectors reveals critical insights into workplace dynamics and productivity enhancement strategies.

Manufacturing Sector Insights: In the production environment observed, particularly in meat and milk processing, significant ergonomic challenges were identified, such as extreme temperatures and wet working conditions. These factors directly impact worker health, safety, and performance. The analysis highlighted that while certain environmental conditions like temperature regulation and proper footwear are addressed, there remains room for improvement in ensuring optimal ergonomic conditions. The use of ergonomic tools and equipment, coupled with ergonomic training, emerged as vital strategies to mitigate risks and enhance operational efficiency. Moreover, the time study conducted in the milk production process demonstrated a clear correlation between extended break times and improved worker efficiency, underscoring the importance of ergonomic considerations in scheduling and workload management.

Service Sector Insights (Hospital): In the hospital setting, specifically in pediatric outpatient clinics and emergency departments, efficiency optimizations were driven by strategic staffing adjustments and operational improvements. The analysis revealed challenges related to patient throughput, staff workload management, and facility utilization during peak and non-peak hours. By employing efficiency calculations and staffing optimization strategies, such as adjusting doctor-to-patient ratios and implementing flexible staffing protocols, significant improvements in patient care delivery and operational efficiency were achieved. These initiatives not only enhanced clinic productivity but also contributed to better patient outcomes and staff satisfaction.

Cross-Sector Ergonomic Strategies: Across both sectors, the integration of ergonomic principles proved crucial in addressing workforce challenges, including fatigue, safety concerns, and productivity losses. The proposed strategies encompassed ergonomic equipment design, technological innovations like virtual reality and artificial intelligence, and interdisciplinary collaboration. These approaches aimed not only to mitigate existing ergonomic challenges but also to foster a proactive and sustainable ergonomic culture within organizations. By emphasizing continuous improvement and adaptive ergonomic solutions, workplaces can adapt to evolving tasks, employee preferences, and technological advancements while promoting a healthy and efficient work environment.

Future Directions: Looking ahead, future research and initiatives in ergonomics should focus on emerging trends such as remote work environments, global perspectives on cultural influences, and adaptive ergonomic solutions. These areas present opportunities to further refine ergonomic practices and enhance their applicability across diverse work settings and geographical contexts. By leveraging advancements in technology and ongoing education, organizations can continue to innovate and optimize work environments to maximize efficiency, promote employee well-being, and maintain competitive advantage.

Finally, the synthesis of ergonomic insights and efficiency strategies underscores the transformative impact of ergonomic interventions in improving worker health, safety, and performance across manufacturing and service sectors. By prioritizing ergonomic design and implementing tailored solutions, organizations can create sustainable workplaces that optimize productivity and support the holistic well-being of their workforce.

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Conflict of Interest

No conflict of interest is declared by the authors.

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