Karelia University of Applied Sciences
Bachelor of Engineering, Industrial Management

Qualitative and Quantitative Analysis of Manpower During Peak and off-Peak Load

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Thesis, November 2024

www.karelia.fi

THESIS
November 2024
Degree Programme in Industrial Management

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Title
Qualitative and Quantitative Analysis of Manpower During Peak and Off Peak-Load
Commissioned by: Qadri Group of Engineering, QadCast and QEN

This thesis illustrates a comprehensive qualitative and quantitative analysis of workforce management at Qadri Group, focusing on the challenges faced during peak and off-peak seasons. The research identifies critical issues related to staffing, workload management and demand forecasting which can lead to overstaffing or understaffing. Through precise data collection from different departments and employing methodologies such as time and motion studies, this research outlines the importance of optimizing workforce efficiency to improve operational practices and customer satisfaction.

The key findings underline the importance of a flexible and adaptative workforce, trained in multiple abilities in order to effectively meet dynamic demands. The study further explains theoretical frameworks such as Human Capital Theory and the Job Characteristic Model, which provide insights into the impact of employee motivation and organisational culture on productivity. Several solutions for enhancing staff management, including demand forecasting, lean management principles, and technology integration, are recommended to address identified challenges and increase overall productivity.

The findings of this thesis will help Qadri Group implement successful workforce strategies that not only improve efficiency but also build a supportive work environment, resulting in sustained business performance and a competitive advantage in the manufacturing sector. The financial implications of these methods are also examined to identify potential cost reductions and profit increases.

Language	Pages 82
English	Appendices 3
	Pages of Appendices 4

Keywords
workforce management, time and motion study, productivity optimization, peak and off-peak load, qualitative analysis, industrial engineering, cupola furnace analysis, REBA (Rapid Entire Body Assessment) analysis and labour efficiency.

Contents

1 Problem statement

Qadri Group is a prominent manufacturer of heavy machinery parts in Pakistan for the sugar and non-sugar sectors. Qualitative and quantitative analyses were performed on the workforce during peak and off-peak seasons. Qadri Group finds it difficult to maintain appropriate staffing and manage workloads to meet the fluctuations of demand in their business operations. Maintaining the optimum number of employees for both peak and off-peak seasons is challenging for the company. Moreover, Qadri Group is having difficulty in predicting demand and being able to adjust the workforce accordingly. If too many employees are employed, this can constitute overstaffing. If too few employees are employed this can constitute understaffing.

During peak periods, workers are overburdened, and the work is delayed. At this point, customer satisfaction decreases. On the other hand, too many workers during the off-peak period will be a waste of labour costs, without increased productivity, which will weaken the company’s business performance. The problem described requires more advanced workforce management approaches based on accurate demand forecasting.

However, Qadri's group practice lacks the precision and adaptability necessary to quickly respond to these challenges. Although simulation models and personnel analysis models have been used, they have not been fully integrated or optimized. In addition, there is a lack of comprehension regarding the quality factors influencing human resource practices across application cycles, such as employee satisfaction and workforce atmosphere.

The aim of this thesis is to examine and assess the use of quantitative methods, such as predictive analysis, and qualitative assessment of employee characteristics to create a comprehensive and effective approach to human resource management at Qadri Group. By implementing these methods, the company can improve its ability to manage the dynamics of employees during peak and off-peak periods and ensure better balance, efficiency, and responsiveness.

1.1 Project deliverables

To determine the optimal resistance of the workers required during peak and off-load periods.

Establish the skill and skill level required for optimal ability or strength.

Compare the proposed capacity with the current workforce and calculate the under/over variance.

Financial implications of differences between proposed and actual strength.

1.2 Introduction

This thesis is commissioned by Qadri Group of Companies, located at Lahore in Pakistan. Qadri Group is a major manufacturer of heavy machinery components for the sugar, cement, chemical, fabric and energy sectors and serves as one of the biggest vendors of these products. It was founded in 1890, the company started with a small foundry in Lahore and has expanded into a global enterprise for industrial equipment. It has currently around 1200 employees. (Qadri Group, 2020).

Workforce improvement is an urgent need for any labour organization and any business company or manufacturing company. An optimized workforce will give the best results and the best use of available resources. Good management of manpower in a difficult time or changing time is a very big challenge for many companies. However, Peak and off-peak seasons demand changes in different levels like staffing, and lack of management during these periods can lead to an increase in cost, reduce company productivity, increase lead time, cycle time, and even in employee discomfort and frustration.

This overview refers to the steps of knowledge on the qualitative and quantitative analysis of manpower during peak and off-peak loads, with a mindset of focusing on or identifying the best methods, challenges and strategies for improvement. Workforce analysis is extremely implemented in the world of business to optimize the inner workings of companies.

As a result, decisions are taken based on these working and the findings throughout the same time taking into account how much profit a company makes. In this thesis two types of data are analysed and monitored, qualitative and quantitative. Quantitative data focuses on numbers and can be used to produce quantitative analysis. For example, employee strength, employees age, geography, and financial status are all quantitative data. Nevertheless, qualitative data involves data that is monitored. This data can be subjective and depends on the feedback or information of the person recording it. For example, employee skills, behaviours, and perceptions. The goal of this thesis is to establish a comprehensive background for the study of Qadri Group's manpower strategy.

Time and motion study, in the evaluation of industrial operations, is the research of the time spent attending to the various motions of a job or sequence of operations. In the early 20th century, time and motion studies were for the very first time conducted in the United States in offices and factories. Work with quantitative measures on a large scale. This analysis was also used to help compare activities and check human and equipment efficiency and structural condition. (Britannica 2014)

The target areas of the project are Qadri Casting, known as QadCast, and Qadri Engineering Machine Shop, known as QEN. The project is mainly based on the industrial engineering research of floor optimization using the term time study and the learning of motion using a real-time learning method. In a machine shop, man-hours vs machine-hours theory helps you get the best workers you need. In this study, the FLS-19 hammer of the cement industry and the FLS-08 Grate plate of non-sugar were chosen and carried out a time and motion study. At QEN, the research was done on the bottom roller frame of the Lotus mill. The result of the study includes a quantitative and qualitative analysis of the employees in the two sectors of the company. The subject research also includes a multi-skilled workforce model and training pool model for existing and newly hired employees. The findings of this study will be analysed for future study purposes in the industry to optimize the workforce and achieve optimal profits and sales. The financial impact of the project will help identify the financial benefits to the company after the implementation of this project. An optimized workforce guarantees the best use of available human resources to achieve optimal performance.

The motivation for this thesis is the need to optimize the workforce and identify the bottlenecks of Qadri and Qadcast processes (Peak and Off-Peak seasons).
Both units of the company are currently operating below their full capacity due to the lack of an optimized workforce.
The main objectives of this project are as follows:
Calculation of manpower assumed to be 100% capacity (single movement and double movement shift).
Calculate the optimum capacity at peak and off-peak periods.
Calculate the difference by comparing the current capacities with the expected capacity.
Use the difference to calculate the financial implications of this change.
For the proposed forces, define the skill levels required for each department/machine family for the different positions (guardian, manager and assistant).

This thesis presents the observations made and the proposed solutions supported by these observations. The report begins with a description of the data collected and the methodology used for analysis. Time and motion study statistics are described along with results from the study. Finally, conclusions will be based on the statistics and propositions will be given for improvements and more research to be carried out in the future.

2 Data collection

The following data was collected from available sources to support the observations and to achieve the optimal required strength.

Data from HR on current labour strength, including permanent and contract employees. Human Resources skills matrix data. IPPCs' machine booking capacity statistics. Production order data from the production manager.

Basic cost data from administrative and production departments.

Workers are organized by sections in both QadCast and Qadri Engineering.

2.1 Working methodology

Understanding and Evaluation of the provided data or information. Identifying important and non-critical areas on floor layout. Visit QadCast with the supervisor, head of production, and production engineers. Collecting data in collaboration with IPPCs and inspectors, as well as authorized personnel. Selection of tasks and activities to conduct time analysis and motion studies. Designing Excel sheets for data entry and machine-generated queries. Using the log time method, one can observe the times by using the direct reading method for the meeting time.

Calculate average observed time, average time, and standard time by adding manpower: personal need, fatigue, and delay (PFD) costs. Calculations of Labor productivity and efficiencies. Calculation of labour hours and machine hours.

Comparison of returns to calculate variance. The workers' ultimate power is assessed, based on their section.

2.2 Workflow efficiency optimization

Workforce management allows a company to maintain productivity, especially when demand changes. An often-used method in identifying functional inadequacies Time and Motion Study By using data on the timing and nature of different activities, companies like the Qadri Group can streamline their operations processes (as a portion of total lead-time) which are not adding value to timely delivery. (Taylor, 1911; Barnes, 1980). Through this process of optimization, the company can keep a high productivity rate even in tumultuous times with variable demands.

2.3 Managing workload balance

Finally, time-motion studies help in the equal distribution of work among labourers. They provide management with the variables they can use to share the amount of work across a team, understanding which tasks are more time-consuming but also effortful. (Barnes 1980 and Niebel & Freiwalds, 2013). This method will make a great difference in Qadri Group management by using this method, they make sure that even when productivity is low every worker shall be engaged. It is possible to reduce or decrease the bottlenecks and increase effectiveness at the same time through the distribution of the work.

2.4 Supporting decision-making based on data

The key advantage of using time and motion study is that it gives indisputable data to help make better decision-making. Qadri's group could use this analysis to better adjust staffing levels and resource allocations using the data from these studies, especially during peak and off-peak periods (Barnes, 1980; Gilbert & Gilbert, 1917). Using data-driven methods, the firm can then prepare for potential changes in demand and attempt to avoid hiring less people at any time.

3 Theoretical frameworks in workforce management

The theoretical frameworks are tools that help guide research by giving a clear idea of how different factors are supposed to work together, based on existing theories. They help us understand, explain, and predict events. (Creswell, 2014, 60). In workforce management, these frameworks are important because they help us understand the complex relationships in a workforce, making sure that we study workforce issues in an organized way. (Johnson, 1961, 23-24)

The Industrial Revolution had an impact on personnel planning throughout history when it came to effective Labour management. Earlier research focused only on personnel allocation strategies to increase the output while minimizing costs incurred throughout the process. Later, operational research further advanced in the mid-20th century with enhanced quantitative methods such as linear programming and queuing theory to handle manpower concerns. (Johnson, 1961).

All seasonal businesses face difficulty while managing variations in workforce demand. So, the primary challenge is to align the workforce according to the fluctuating needs throughout the year. The basic strategy is to ensure the availability of a consistent workforce which will result in a period of idle time and at the time of overtime requirement, adding workforce at the time of peak load season, changing workdays, and adding compensation. (Hung, 1998). Here are a few important theoretical frameworks in workforce management.

3.1 Human capital theory

Human capital theory illustrates the economic worth of an individual's skills, capabilities, and knowledge, which are viewed as investments that give returns comparable to physical capital. It depicts that employees are assets of a company, and the management of the Workforce is a key area of focus in an organization. It includes optimization and allocation of the workforce for the benefit of the organization and their values can be increased by training, education and development. By investing in personnel benefits, the organization can improve the performance and skills of the workforce, ultimately enhancing productivity and revenue. The benefit of investing in human capital, such as increased productivity, innovation, and lower turnover should surpass the expenses. So, this idea is frequently used in workforce planning and talent management to justify investments in staff development programs. (Becker, 1964)

3.2 The equity theory

The equity theory investigates how people see fairness in social and professional interactions. It proposes that people estimate fairness by comparing their own efforts, abilities and performance to incentives like as money, recognition, or benefits to that of others in comparable situations. It stresses the need for justice in the workplace. Therefore, employees may feel motivated and demotivated depending on whether they perceive equity or inequity. Equity theory is critical when it comes to salary, reward system, employee concerns, and organizational justice. (Adams, 1963)

3.4 Job Characteristics Model (JCM)

Hackman and Oldham's JCM model proposed specific job features such as a variety of skills, seeing a task from start to end, and having control over how work is performed, impacting employee motivation, satisfaction, and performance. This model has played an important role in designing jobs, helping to create roles that are demanding and rewarding for workers. (Hackman & Oldham, 1976)

4 Qualitative analysis

Qualitative data is information that comes from data that is observed. It can be subjective, depending on how the person sees and records it. For example, a worker's skills and literacy are types of qualitative data. This data helps, explains and supports numerical data or quantitative data. In a project, qualitative analysis looks at things like workforce skills, age group, literacy rate etc.

4.1 Flexible and adaptable workforce

One important quality of the workforce is its ability to be flexible and adaptable as per requirement. During peak load time when work increases during a certain time of year, it is a challenge for workforce management to manage shifts and workloads for employees. Workers who can switch easily between tasks are more valuable during busy seasons when more productivity and speed are expected. To achieve this adaptability, workers need skill development and training on a regular basis. In this way, workers can perform different tasks and operate different machines effectively. (Kok & Kasa, 2021)

4.2 Trained and skilled workforce

The skill level of workers is very important as they are trained in how well manufacturing operation is handled during both busy and slow periods. A skilled workforce can increase productivity without lowering quality. This workforce can be used for training, maintenance, and continuous improvement in the process. It is necessary to reduce downtime and make efficient operations even when demand is slow. (Smith, 2022)

4.3 Morale and motivation of the workforce

Employees' morale and motivation can be greatly affected during busy and slow times. In peak- periods, a high workload can cause exhaustion if morale and motivation are not handled effectively. On the other hand, during a slow period, less work can cause lower productivity. Workers are required to be engaged and well-motivated throughout the year to sustain a productive team. Strategies like recognizing good work, fair pay, good bonuses, and chances of promotion can keep morale high. (Johnson & Lee, 2023)

4.4 Diversity and composition of the workforce

A team with diverse experiences, skills, and backgrounds can handle peak and off-peak load times better. When they share together different ideas and solutions it is helpful for quick decision making during busy periods. The diverse nature of the team comprises of quality of adapting and doing work well together which enables them to deal stress of changing work in a better way. (Rodriguez & Patel, 2023)

4.5 Management and Leadership

Management and leadership play a very important role in handling workers in busy and slow demand periods. A capable and strong management and leadership make sure that the team works together, stays motivated, and is ready to achieve the required productivity irrespective of workload. (Walker, 2022)

4.6 Organizational culture and communication

Organizational culture and communication are important to how well a team acts during seasonal and non-seasonal times. A culture that develops a system of open communication, involving employees' independent contribution of suggestions to process improvement can create a stronger and more united team. Constructive communication stays informed, involved, and well-focused toward achieving the company's goals which keeps them ready for seasonal change. (Garcia & Thompson, 2022). In a strong organizational culture, employees align with the company's core values and goals, and new team members quickly embrace and integrate these shared principles into their work (Tedla, 2016).

In short, analysing the human factors in manufacturing, like flexibility, skills, morale, diversity, leadership, and organizational culture, is key to managing peak and off-peak load periods in an industry. Focusing on these aspects will ensure the building of a strong, well-trained, reliable, and adaptable workforce that can cope with seasonal demand effectively.

5 Quantitative analysis of manpower in workforce management

Quantitative is all about the use of statistical methods and mathematical processes to advance and deal with workforce requirements properly. One well-known method, workforce request forecasting, is historical data to find out future employees' needs. Research has shown that correct forecasting can incredibly reduce labour costs while increasing service levels (Taylor & Huxley, 1989). Most methods used in this process include time and motion studies, regression models, machine learning, and algorithms (Hyndman & Athanasopoulos, 2018). These approaches allow companies like Qadri Group to optimize their workforce system and maintain operational efficiency. Companies like Qadri Group can also take advantage of Predictive analytics. The use of predictive analytics, which involves the use of analysis of past data, often relies on machine learning techniques to help companies anticipate busy periods. Smith (2020) states that the use of newer tools enables businesses to plan for high demand by allocating resources accordingly. The companies can ensure that they have enough staff on hand without overstaffing by predicting the peak demand for workers which saves money and boosts productivity. Predictive analytics can be used by Qadri Group to improve resource management and customer satisfaction, enabling them to respond to anticipating workload changes with proactive measures (Smith, 2020).

Another useful approach to workforce management is through simulation models. Virtual scenarios are generated in these models to simulate employee behaviour during peak and off-peak hours, which also offer a secure environment for testing different employee strategies. These simulations, as noted by Jones and Taylor (2021), demonstrate how variations in staffing levels impact performance over time and enable companies to plan more effectively. These models enable Qadri's team to explore alternative products without compromising on real-life products, enabling them to determine the most effective approach to meet the needs of employees in different demand cycles (Jones & Taylor, 2021).

5.1 The importance of ergonomic solutions and safety measures in manufacturing

In the manufacturing sector, ergonomics is the practice of studying human body performance in workplaces. The goal of ergonomics is to reduce risk factors and promote productive work postures by designing activities such as workspaces and equipment that are in the best interest of the workers. Significant benefits can be achieved by putting ergonomics solutions into practice, such as redesigned equipment, altered workstations, or administrative measures like job rotation. These modifications promote a healthier workplace in addition to reducing the chance of accidents. They can increase workplace satisfaction, lessen stress and exhaustion, and make workers more comfortable. These advancements, in turn, frequently result in increased productivity and a decreased prevalence of MSDs, benefiting both businesses and employees. In summary, the manufacturing sector depends heavily on comprehending and using ergonomics principles. It will remain a crucial component in preserving workplace safety, advancing production methods, and raising employee well-being generally as we move through 2023. (Brown, 2023)

5.2 Consequences of Implementing Poor Ergonomics

One of the biggest problems in manufacturing is Poor ergonomics. It is sometimes defined by conditions that push workers into awkward postures, necessitate heavy lifting, or necessitate long durations of repetitive action. These circumstances reduce worker comfort and can lead to musculoskeletal illnesses (MSDs). MSDs include a variety of inflammatory and degenerative disorders affecting the muscles, ligaments, tendons, and bones. MSDs are a real danger to worker productivity and health. They can result in prolonged absences, reduced productivity, and, in severe situations, permanent incapacity. Furthermore, they contribute to rising healthcare expenses and can have a knock-on effect, lowering morale and contributing to additional inefficiencies in the production environment. (Brown, 2023)

6 Obstacles in managing peak and off-peak-loads

In the workforce sector handling peak and off-peak seasons can be very challenging for companies. During peak season companies usually face a lot of issues with overstaffing which significantly affects the labour costs and potential disorganization (Pfeffer, 1994). On the other hand, during off-peak season, understaffing can result in many worse cases like burnout, frustration, tiredness, less commitment, and decreased service quality (Schaufeli, 2009). However, applying these limits requires an essential way to deal with labour force planning, including the use of flexible staffing game plans and temporary employees. This would be beneficial for the company group since they are already facing some issues in this sector.

7 Strategies for optimization of workforce management

Good personnel management is very important in industrial engineering, especially in busy and slow periods. The goal is to balance the workforce to maximize productivity while keeping costs low. Here are some strategies that can help.

7.1 Demand forecasting and scheduling

Accurate demand forecasting is the foundation for workforce management. Companies can plan their staffing better by knowing when peak and slow times will happen. Advanced methods can help predict these changes like time series analysis and machine learning models (Dinu & Serban, 2019). Companies that coordinate workforce schedules with projected demand can make sure that they have the right number of workers at the right time, eliminating overstaffing during slow times and understaffing during peak times.

7.2 Flexible Workforce Model

Using flexible workforce strategies is key to effectively managing the changing workloads. Basically, this involves the hiring of temporary, part-time, or contract workers who can easily be handled added or reduced based on the level of demand (Kumar & Panneerselvam, 2019). Furthermore, the training of employees to handle multiple roles within the company overall boosts the flexibility of the work. This allows staff to reassign their duties in peak load time while off-peak load time can be utilized for other essential activities like maintenance, training, or other important tasks that support business.

7.3 Lean for Workforce Management

Lean principles, which aim to cut waste and boost efficiency, can be used to manage the efficiency of workforce management. This means simplifying the processes so that employees focus on value-added tasks. During a slow period, lean management stresses the need to cut back on unnecessary labour working hours by identifying and removing non-essential activities (Rother & Shook, 2003). This Lean management principal application on workforce management not only lowers labour costs but also increases employee productivity.

7.4 Shift planning and scheduling software

Shift planning software can ease workforce management efforts to improve shift planning by matching demand with workforce availability. These tools allow schedules to be adjusted easily, ensure enough staff during peak time, and cut labour costs when it is slow. (Ramani & DeHart, 2020). The software also helps workers to communicate better, reducing downtime and boosting overall efficiency.

7.5 Employees' performance and incentives

Rewarding employees for good performance during peak working season can enhance productivity. Offering bonuses, overtime pay, or flexible hours can motivate them hard when it is needed (Lam et el., 2018). Employees can be encouraged to take part in training and development to improve their skills and prepare for future busy times when the workload is off. Good training and skill lead to better performance and productivity which will ultimately add incentives.

Managers should examine a variety of elements while developing strategies, including company size, age, competition, customers, suppliers, stakeholders, distribution methods, regulation, and technology. These factors will influence outcomes and performance (Etukudo, 2019).

These strategies offer a complete way to improve workforce management in industrial settings and help companies meet demand efficiently while keeping labour costs under control.

7.6 Benefits of technology

Technology has always been a big help factor in manpower management. Because of this organizations have the ability to monitor their workforce metric in real time and make dynamics staffing adjustments with the help of workforce management software and advanced analytics. The help of machine language and artificial intelligence is significantly increasing as they enable greater and better precision in making predictions and improved decision-making capabilities. (Boehmke & Greenwell, 2019). These technologies don’t just increase productivity but also facilitate the ability to quickly adapt to changing work demands. Which is a very important factor for Qadri Group.

8 Summary

The literature review highlights the challenges faced by Qadri Group in managing the workforce demands during peak and off-peak periods. The company struggles with maintaining the right number of employees, leading to overstaffing or understaffing issues. The review emphasizes the importance of adopting advanced workforce management strategies, including accurate demand forecasting, flexible staffing, lean management principles, and the use of technology. By implementing these approaches, Qadri Group can optimize its workforce, improve efficiency, control labour costs, and enhance overall productivity, ensuring better alignment with fluctuating seasonal demand.

9 Calculation at Qadcast first unit

The calculations are performed to find the respective sections' standard time and corresponding efficiencies based on time and motion study. FLS-19 Hammer and FLS-08 Grate plates were selected and performed a stopwatch time study on the entire process line.

The general formulas of time and motion study are mentioned below:

$$\text{Performance Rating (PR)} = \frac{\text{Workers Speed}}{\text{Expected Speed}}$$

$$\text{Normal time } (T_N) = \text{Observed time} \times \text{PR}$$

$$\text{Standard time } (T_{Std}) = \text{Normal time} \times (1 + \text{PFD})$$

$$= \text{Normal time} \times \frac{(1 + \text{Allowance percentage})}{100}$$

Note: Allowance percentage was given= 15%

(Shahriar, 2019, 2)

$$\text{Standard Hours} = \text{Units produced}(Q) \times T_{Std}$$

(Stevenson, W. J. 2018, 347)

$$\text{Worker Efficiency} = \frac{\text{Normal Hours}}{\text{Standard Hours}} \times 100$$

(Groover, 2021. 213)

$$\text{Manpower Efficiency} = \frac{T_{Std} \times Q}{\text{Standard Hours} \times \text{Number of workers}}$$

(Kumar, S. A., Suresh, N. 2009, 485)

Idle Time = Standard Time -Total Time

(Barnes, R. M. 1980, 159)

PFD = Personal need, fatigue and delay

HFF = High-Frequency Furnace

QHSE = Qadri health and safety engineering

10 Time and motion study FLS-19 hammer

The following represents the results of the time and motion study conducted on the FLS-19 Hammer, detailing various work elements involved in the production process (Table 1). Each work element is assessed across five trials, measuring the time taken (in hours, minutes, and seconds) for tasks such as furnace lining, feed sorting, and pouring into mould.

HFF section									
Work Element	**Measurement of Time (hr/min/sec)**					**Average time**	**PR**	**Normal Time**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Furnace Lining	8 hours	_	_	_	_	8 hours	_	_	8 hours
Feed sortingand addition	2.20 hours	_	_	_	_	2.20 hours	_	_	2.20 hours
Temp Monitoring	41.25 Sec	41.05 sec	40.57 Sec	44 Sec	42.23 Sec	41.82 sec	1.05 sec	43.91 sec	50.50 sec
Flux Addition	2.33 min	2.50 min	3.02 min	2.42 min	2.52 min	2.55 min	1.30 min	3.32 min	3.82 min
Slag Removal	44 Sec	50 sec	66 sec	50 sec	60 sec	54 sec	1.45 sec	78.30 sec	90.05 sec
Temp Monitoring	42.25 sec	41.05 sec	49.59 sec	45 sec	42.25 sec	44.03 sec	1.05 sec	46.23 sec	53.16 sec
Flux Addition	2.40 min	2.54 min	3.11 min	2.45 min	2.52 min	2.60 min	1.2 min	3.12 min	3.59 min
Slag Removal	43 sec	50 sec	60 sec	45 sec	43 sec	48.2 sec	1.40 sec	67.48 sec	77.60 Sec
Pouring into Ladle	1.22 min	1.36 min	2.12 min	1.58 min	2.22 min	1.70 min	1.82 min	3.09 min	3.56 min
Temp Monitoring	41.15 sec	41.36 sec	40.58 sec	42.1 sec	43.22 sec	41.68 sec	1.05 sec	43.76 sec	50.33 Sec
Preheating before pouring	53 sec	49 sec	54sec	43 sec	60sec	51.8sec	1.40sec	72.52sec	83.40Sec
Pouring into mould	26 sec	42 sec	30 sec	34 sec	43 sec	35 sec	1.67sec	58.45ec	67.22Sec
Total Average Time: 624.13min = 10h24min							Total Standard Time: 630.84 min = 10h30min		

Table 1. HFF section FLS-19 time and motion study results.

The table demonstrates the time spent on each activity, yielding an overall average time of 624.13 minutes (10 hours and 24 minutes) and a total standard time of 630.84 minutes (10 hours and 30 minutes). A notable notice is the extended duration of the "Furnace Lining" task, which takes 8 hours and emphasizes its relevance in the production cycle. Other activities, such as "Temp Monitoring" and "Flux Addition," have varying timings, indicating fluctuations in efficiency.

Performance rating (PR) indicates changing levels of worker efficiency. For example, the "Feed Sorting and Addition" operations are consistently efficient, whereas "Slag Removal" and "Pouring into Ladle" have greater time variability, indicating possible areas for improvement. This data emphasizes the value of time tracking in improving operational efficiency and productivity in the HFF department.

Mould Closing									
Work Element	**Measurement of Time (min)**					**Average time**	**PR**	**Normal Time**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Mould Preparation for Pouring									
Application of Adhesive on Parting Line	0.66	0.67	0.71	0.70	0.72	0.69	1.11	0.76	0.89
Placement of Sand on Parting Line	2.01	2.04	2.10	2.16	2.26	2.11	1.12	2.37	2.78
Placement of Card Boards on Gas outlets	0.93	0.96	0.98	0.99	1.03	0.97	1.13	1.10	1.3
Placement of clamps	4.11	4.21	4.32	4.41	4.25	4.26	1.08	4.60	5.41
Placement of weight	2.34	2.46	2.67	2.75	2.66	2.57	1.20	3.09	3.63
Placement of Carbide Filter	0.09	0.10	0.08	0.09	0.08	0.08	1.15	0.10	0.11
Total	10.14	10.14	10.90	11.01	11.0	10.68	**6.79**	12.02	14.12

Table 2. Mould closing process time analysis.

A represented and detailed analysis of the time measurements for the mould closing process, evaluating each work element across five observations. It includes calculations for average time, performance ratio (PR), normal time, and standard time (table 2). The total time for the mould closing process is approximately 10.68 minutes.

The most time-consuming task is the placement of clamps, taking an average of 4.26 minutes, suggesting it may be a bottleneck, while the placement of the carbide filter requires only 0.088 minutes, indicating greater efficiency. This analysis highlights the varying contributions of each work element to the overall time, emphasizing the need to optimize more time-intensive tasks to improve operational efficiency and productivity.

Melt Pouring into Mould									
Work Element	**Observations of Time (min)**					**Average time**	**PR**	**Normal Time**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Placing of Mould of Pouring	0.39	0.38	0.40	0.37	0.36	0.38	1.11	0.42	0.49
Pouring into Mould	0.70	0.68	0.65	0.70	0.63	0.67	1.11	0.74	0.87
Fire Torch for Gas Removal	0.73	0.85	0.80	0.83	0.82	0.80	1.16	0.93	1.1
Temp Monitoring	0.40	0.45	0.42	0.45	0.39	0.42	1.17	0.49	0.58
Flux Addition	0.092	0.093	0.100	0.100	0.096	0.096	1.09	0.10	0.12
Exothermic Powder Addition	0.094	0.088	0.098	0.100	0.093	0.094	1.17	0.110	0.13
Slag Removal	0.184	0.179	0.198	0.183	0.195	0.187	1.16	0.217	0.25
Total	2.59	2.72	2.66	2.733	2.58	2.76	7.97	3.007	3.54
Total	12.73	12.86	13.56	13.74	13.58	13.33	14.76	15.024	17.66
Idle time ofworkers between every mould filling	2.46	2.4	2.05	1.96	2.04	2.18		2.47	2.90

Table 3. Melt pouring into mould time analysis.

An Analysis of the melt pouring process into the mould, detailing the time taken for various tasks, such as placing mould, pouring, and monitoring temperatures, based on five observations. The total average time for these tasks is 2.76 minutes, while the entire melting operation takes 13.33 minutes.

Performance ratings (PR) for all tasks are above 1, indicating efficient operation compared to the standards illustrated (in Table 3). However, the idle time of approximately 2.18 minutes between mould fillings suggests a potential area for improvement to boost productivity. The variations in task times indicate a need for consistency and possible standardization in procedures to improve the melt-pouring process. Overall, this table is important for identifying strengths and opportunities for operational improvements in the melt-pouring stage, linking back to insights from the previous analysis.

Ladle Making									
				1Ton					
Work Processes	**Observations of Time (min)**					**Average time**	**PR**	**NormalTime**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Die forming	12.8	12.5	13.2	13.5	13.3	13.06	1.055	13.77	16.2
Sleeve placements	6.22	6.43	6.7	6.49	5.88	6.34	1.153	7.32	8.6
Sand mixing	18.33	18.61	18.88	17.13	18.75	18.34	1.103	20.22	23.79
Ladle lining	24.22	22.46	22.66	23.35	23.88	23.31	1.078	25.13	23.34
TOTAL	**61.57**	**60.00**	61.44	**60.47**	**61.81**	49.01	1.020	56.5	71.93
				250kg					
Work Processes	**Observations of Time (min)**					**Average time**	**PR**	**Normal Time**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Die forming	6.44	6.8	13.2	13.5	13.3	10.64	2.110	22.47	22.47
Sleeve placements	6.22	6.43	6.9	6.47	5.90	6.20	1.155	7.16	7.16
Sand mixing	18.35	18.63	18.86	17.13	18.75	18.34	1.101	16.67	16.67
Ladle lining	24.24	22.46	22.66	23.35	23.88	23.32	1.078	25.15	25.15
TOTAL	55.25	54.32	61.62	60.45	61.83	58.5	1.140	71.45	71.45

Table 4. Ladle making time observations (1 Ton, 250 kg).

A representation of the observation time for two different lead-making processes: one for a 1-ton capacity and the other for a 250-kg capacity. Each process is broken down into specific tasks, including die forming, sleeve placements, band lining, and ladle lining. For the 1-ton ladle, the average time for each task varies, with die forming taking an average of 13.06 minutes and ladle lining taking 23.31 minutes, resulting in a total process time of 49.01 minutes. On the contrary, the

250 kg ladle shows a more efficient average time for die forming at 10.64 minutes, with the total process time summing up to 58.5 minutes (table 4). This indicates a significant difference in time efficiency between the two capacities, highlighting the impact of scale on production processes. The performance ratings (PR) and standard times (Std. Time) also suggest variations in efficiency across the tasks, which could inform future operational improvements.

Carousel Moulding										
Work Processes	Observations of Time (min)					Avg time	PR	Normal Time	Std. Time	Efficiency %
	1st	2nd	3rd	4th	5th					
Mould Box Placement										
Box Placement and Fitting	0.51	0.57	0.52	0.63	0.58	0.56	1.20	0.67	0.79	84.81
Releasing Agent Application	5.21	5.00	5.62	5.39	5.19	5.28	1.13	5.96	7.02	84.90
ReleasingAgent Drying	13.01	11.71	13.52	12.00	12.38	12.52	1.15	14.40	16.94	85.00
Box checking	5.11	5.81	5.39	5.89	5.69	5.57	1.16	6.47	7.61	85.01
Mould box cleaning	5.70	5.00	5.29	5.22	5.90	5.42	1.20	6.51	7.65	85.09
Total	29.54	28.09	30.34	29.13	29.74	29.35	5.84	34.0	40.0	85.00

Suggestions

While waiting for the release agent to dry, the worker should use this time to get the paint and sand mixer ready. By preparing these materials in advance, the worker can ensure that everything is set up and organized for the next steps in the process, minimizing any potential delays once the release agent is fully dried. This helps improve efficiency and keeps the workflow running smoothly.

Table 5. Carousel moulding process time observations.

Details of time observations for various tasks in the FLS-19 hammer's carousel moulding process, including average time, performance rating (PR), normal time, standard time, and efficiency percentage are demonstrated in (table 5).

The task "Box Placement and Fitting" has the shortest average time (0.56 minutes) and an efficiency of 84.81%, while "Releasing Agent Drying" has the longest average time (12.52 minutes) with an efficiency of 85.00%. The total average time for all tasks is 29.35 minutes, with an overall efficiency of 85.00%.

This analysis reveals variability in task efficiency, highlighting areas for potential improvement, especially in more time-consuming tasks.

Sand Filling										
Work Processes	Observations of Time (min)					Average time	PR	Normal Time	Std. Time	Efficiency%
	1st	2nd	3rd	4th	5th					
MachineShifting	0.21	0.22	0.19	0.20	0.19	0.20	1.12	0.22	0.26	84.61
Box Placement Under Feeder	0.13	0.14	0.10	0.12	0.11	0.12	1.16	0.13	0.16	81.25
Placing of Sprue / Core	0.30	0.32	0.28	0.29	0.32	0.30	1.12	0.33	0.39	84.61
Pouring of sand (min)	2.13	2.06	2.15	2.16	2.34	2.16	1.15	2.49	2.93	84.98
Adjusting sand + ramming	3.35	3.32	2.78	3.09	2.75	3.06	1.20	3.67	4.31	85.15
Total	6.12	6.06	5.5	5.86	5,71	5.84	5.75	6.84	8.05	_
OperatingTime	0.166	0.193	0.184	0.168	0.176	0.17	1.15	0.20	0.20	100

Table 6. Sand filling process time observations.

A Provided and detailed breakdown of the time taken for each work element involved in the sand-filling process for the FLS-19 hammer. The observations are recorded across five trials, showcasing the variability in time spent on tasks such as "Machine Shifting," "Box Placement Under Feeder," and others can be seen in (table 6). The average times calculated reveal insights into operational efficiency, with "Machine Shifting" showing an average time of 0.20 minutes and an efficiency of 84.61%. Notably, the task of "Pouring of Sand" takes significantly the second longer position, averaging 2.16 minutes, yet maintains an efficiency rate of 84.98%. Overall, the total average time taken for the sand filling process is 5.84 minutes, indicating an effective management of time across all tasks, contributing to the overall productivity during the hammer's operation.

Mould Cleaning										
Work Processes	Observations of Time (min)					Average Time	PR	Normal Time	Standard Time	Efficiency %
	1st	2nd	3rd	4th	5th					
Mould Analysis	0.09	0.09	0.09	0.09	0.09	0.09	1.05	0.09	0.11	81.81
Air Pressure Cleaning	0.72	0.71	0.69	0.72	0.70	0.71	1.04	0.73	0.86	84.88
Cleaningwith Hand	0.12	0.14	0.11	0.14	0.12	0.12	1.24	0.15	0.18	83.33
Analysis Again	0.06	0.05	0.06	0.06	0.05	0.056	1.19	0.066	0.076	86.84
Total	0.99	0.99	0.95	1.01	0.96	0.97	5.72	1.036	1.22	_

Table 7. Mould cleaning process time observations.

Details of the time observations for the mould cleaning process of the FLS-19 hammer, covering tasks like Mould Analysis, Air Pressure Cleaning, hand Cleaning, and a follow-up analysis. "Analysis Again" shows the highest efficiency at 86.84%, while Mould Analysis has a slightly lower efficiency of 81.81% (Table 7).The total average time for the process is 0.97 minutes, with a standard time of 1.036 minutes, reflecting a well-optimized workflow with only minor efficiency differences across tasks.

Coating/Painting										
Work Processes	Observations of Time (min)					Average time	PR	Normal Time	Standard Time	Efficiency %
	1st	2nd	3rd	4th	5th					
Formation of Paint	-	-	-	-	-					
1st Coat of Paint Brush	3.13	3.22	3.18	3.16	3.17	3.17	1.04	3.29	3.88	84.79
2nd Coat of Paint Brush	2.50	2.49	2.34	2.21	2.27	2.36	1.19	2.81	3.30	85.15
Spraying of Paint	0.43	0.42	0.40	0.39	0.38	0.40	1.19	0.48	0.56	85.71
Coating Inspection	0.10	0.11	0.11	0.10	0.11	0.10	1.10	0.11	0.13	84.61
Total	6.16	6.24	6.03	5.86	5.93	6.03	4.52	6.69	7.87	_

Table 8. Coating and painting process time observations.

Details about the time observations for the FLS-19 hammer's coating and painting process, covering tasks like the application of the first and second paint coats and paint spraying. The first coat takes an average of 3.17 minutes, while the second coat is slightly faster at 2.36 minutes (table 8). The overall process efficiency is 78.79%, indicating room for improvement, particularly in reducing application times to boost productivity.

Firing										
Work Element	**Observations of Time (min)**					**Average time**	**PR**	**Normal Time**	**Standard Time**	**Efficiency %**
	1st	**2nd**	**3rd**	**4th**	**5th**					
Torch Bringing	0.066	0.063	0.084	0.073	0.072	0.071	1.301	0.093	0.102	91.17
Firing	0.502	0.522	0.501	0.492	0.508	0.505	1.062	0.536	**0.631**	84.94
Analysis	0.056	0.056	0.064	0.058	0.057	0.058	1.177	0.068	0.068	100
Firing (additionalrequired)	-	-	0.040	-	0.042	0.041	1.046	0.042	0.042	100
Total	0.624	0.641	0.689	0.623	0.679	0.675	4.586	0.739	0.843	_
X-Y Crane Operation	1.2	1.13	1.2	2	0.99	1.30	1.14	1.48	1.48	100
Bringing of Cores	1.01	1.09	1.12	1.14	1.02	1.09	1.12	0.97	1.09	88.99
Adjusting of Core	2.74	2.68	2.79	3.08	2.90	2.83	3.25	2.83	2.83	100
Placement Of Core (time/core)	3.33	3.30	3.27	3.48	3.39	3.35	3.58	12.01	**12.01**	100
Minor Adjustments	-	1.46	-	95	-	1.46	1.82	0.80	0.80	100
Analysis of mould with core on MNQ	2.33	2.12	2.42	2.40	2.19	2.29	2.57	5.90	6.49	90.90
Total	9.41	10.65	9.6	105.1	9.5	11.02	12.34	22.51	23.22	_

Table 9. Firing process time observations.

Various detailed breakdown of the time observations for various elements involved in the firing process of the FLS-19 hammer. Each work element is analysed based on multiple observations, showcasing the average time taken, performance rating (PR), normal time, standard time, and overall efficiency percentage. Notably, the "Torch Bringing" task shows an efficiency of 91.17%, indicating effective performance, while the "Firing" element achieves an efficiency of 84.94% (table 9). The total time recorded for the firing process, including all observed elements, is 22.51 minutes, which reflects cumulative efficiency across tasks. The data highlights the importance of each task's efficiency in optimizing the overall firing process, which is critical for maintaining productivity in the manufacturing of the FLS-19 hammer.

Fettling									
Work Element	**Observations of Time (min)**					**Average time**	**PR**	**Normal Time**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Head + Riser Cutting	11.80	12.50	12.00	13.8	13.7	12.7	1.22	15.5	17.9
Grinding (surface)cutter	125	122	130	114	133	124.8	1.20	149.7	172.23
Pin + Body + Grinding	156	157	170	172	152	161.4	1.16	187.4	215.5
Cosmetic + Paint	50.6	56	55	53	55.8	54.08	1.63	88.20	101.4
Total	343.4	347.50	367.0	352.8	354.5	353.98		440.8	

Table 10. Fettling process time observations.

The data presented in table 10 provides a detailed observation of the time taken for various fettling processes associated with the FLS-19 hammer. The table illustrates the time recorded for five different work elements, including "Head + Riser Cutting," "Grinding (surface cutter)," "Pin + Body + Grinding," and "Cosmetic Paint." The average times indicate a consistent performance across observations, with "Grinding (surface cutter)" showing the highest average at 124.8 minutes. The Performance Rating (PR) values reflect the efficiency of each process, with the "Grinding" process yielding a PR of 1.03, indicating a need for further analysis to optimize this task. Overall, the total time for the fettling processes sums to 440.8 minutes, highlighting the time investment required for these essential operations.

11 Time and motion study FLS-08

The following Table 11. Represents the results of the time and motion study conducted on the FLS-08 hammer, detailing various work elements involved in the production process. Each work element is assessed across five trials, measuring the time taken (in hours, minutes, and seconds) for tasks such as furnace lining, feed sorting, and pouring into mould.

HFF section									
Work Element	Measurement of Time (hr/min/sec)					Average time	PR	Normal Time	Standard Time
	1st	2nd	3rd	4th	5th				
Furnace Lining	8 hours	–	–	–	–	8 hours	–	–	8hours
Feed sortingand addition	2.20 hours	–	–	–	–	2.20 hours	–	–	2.20 hours
Temp Monitoring	41.25 sec	41.05 sec	40.57 sec	44 sec	42.23 sec	41.82 sec	1.05 sec	43.91 sec	50.50 sec
Flux Addition	2.33 min	2.50 min	3.02 min	2.42 min	2.52 min	2.55 min	1.30 min	3.32 min	3.82 min
Slag Removal	44 sec	50 sec	66 sec	50 sec	60 sec	54 sec	1.45 sec	78.30 sec	90.05 sec
Temp Monitoring	42.25 sec	41.05 sec	49.59 sec	45 sec	42.25 sec	44.03 sec	1.05 sec	46.23 sec	53.16 sec
Flux Addition	2.40 min	2.54 min	3.11 min	2.45 min	2.52 min	2.60 min	1.2 min	3.12 min	3.59 min
Slag Removal	43 sec	50 sec	60 sec	45 sec	43 sec	48.2 sec	1.40 sec	67.48 sec	77.60 sec
Pouring into Ladle	1.22 min	1.36 min	2.12 min	1.58 min	2.22 min	1.70 min	1.82 min	3.09 min	3.56 min
Temp Monitoring	41.15 sec	41.36 sec	40.58 sec	42.10 sec	43.22 sec	41.68 sec	1.05 sec	43.76 sec	50.33 sec
Preheating before pouring	53 sec	49 sec	54 sec	43 sec	60 sec	51.8 sec	1.40 sec	72.52 sec	83.40 sec
Pouring into mould	26 sec	42 sec	30 sec	34 sec	43 sec	35 sec	1.67 sec	58.45 sec	67.22 sec
Total Average Time: 624.13 min = 10hr24 min							Total Standard Time: 630.84min =10hrs30min		

Table 11. HFF section FLS-08 time and motion study results.

A representation of the outcome of time and motion study after conducting an analysis of all the work processes in the HHF section. This process is the same for both FLS-19 and FLS- 08, they have this identical process. Details can be seen in (table 11).

Carousel Moulding									
Work Element	**Observations of Time (min)**					**Average time**	**PR**	**NormalTime**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Mould Box Placement									
Box Placement and Fitting	0.53	0,55	0.56	0.59	0.58	0.56	1.19	0.66	0.76
Releasing Agent Application	5.40	5.55	5.20	5.3	5.50	5.39	1.12	14.81	5.53
Releasing Agent Drying	12.50	12.10	13.00	12.3	12.4	12.46	1.15	4.33	16.48
Box checking	5.45	5.40	5.50	5.8	5.6	5.55	1.16	4.78	5.50
Mould boxcleaning	5.80	5.30	5.20	5.40	5.70	5.52	1.18	4.68	5.39
Total	29.68	28.90	29.46	29.39	29.78	29.48	5.8	29.26	33.66

Table 12. Carousel moulding process time observations (FLS-08).

A Provided observation time for tasks in the carousel moulding process, focusing on mould box placement and tracking five cycles for each task. The "Releasing Agent Application" requires the most time, with a normal duration of 14.81 minutes, indicating a need for precision in this step. Meanwhile, "Mould box clearing" shows significant variation, with a standard time reaching up to 5.30 minutes, possibly reflecting execution inconsistencies or differing levels of worker efficiency (table 12).

Overall, the carousel moulding process takes 29.48 minutes on average, with a standard time of 33.66 minutes. While operations are generally efficient, tasks with higher times suggest areas where further improvements could enhance productivity.

Sand Filling									
Work Element	Observations of Time (min)					Average Time	PR	Normal Time	Standard Time
	1st	2nd	3rd	4th	5th				
Machine Shifting	0.203	0.208	0.182	0.204	0.192	0.197	1.128	0.223	0.223
Box Placement Under Feeder	0.118	0.125	0.108	0.118	0.114	0.136	1.167	0.136	0.159
Placing of Sprue / Core	0.284	0.309	0.277	0.293	0.308	0.294	1.115	0.328	0.328
Pouring of sand (min)	1.141	1.052	1.130	1.151	1.081	1.111	1.095	1.216	1.216
Adjusting Sand + Ramming	1.250	1.372	1.380	1.442	1.321	1.353	1.135	1.192	1.192
Total	**2.996**	**3.066**	3.077	**3.208**	**3.016**	**3.091**	**5.640**	**3.095**	**3.095**
Turnover Operation									
Operating Time	1.861	1.790	1.821	1.782	1.841	1.819	1.045	1.548	1.548

Table 13. Sand filling process time observations (FLS-08).

A Provided time breakdown for the sand filling process in the FLS-08 production system, detailing five work elements across multiple trials:
Machine Shifting averaged 0.197 minutes with a PR of 1.128, yielding a standard time of 0.223 minutes. Box Placement Under the Feeder averaged 0.136 minutes (PR 1.167), with a standard time of 0.159 minutes. Placing of Sprue Core took 0.294 minutes on average (PR 1.115), resulting in a standard time of 0.328 minutes. Adjusting Sand + ramming was the most time-consuming task, averaging 1.353 minutes (PR 1.135) and a standard time of 1.192 minutes. Pouring of Sand averaged 1.111 minutes (PR 1.095), with a standard time of 1.216 minutes. This is demonstrated in (table 13).

In total, the work elements took 3.091 minutes, with a turnover operation time of 1.548 minutes. This analysis highlights areas for potential optimization, focusing on improving efficiency in time-intensive tasks.

Mould Cleaning									
Work Element	Observations of Time (min)					Average time	PR	Normal Time	Standard Time
	1st	2nd	3rd	4th	5th				
Mould Analysis	0.084	0.088	0.090	0.088	0.084	0.086	1.045	0.090	0.090
Air Pressure Cleaning	0.673	0.675	0.687	0.685	0.669	0.677	1.027	0.677	0.696
Cleaning with Hand	0.132	0.126	0.123	0.134	0.127	0.128	1.108	0.115	0.115
Analysis Again	0.058	0.061	0.060	0.053	0.057	0.057	1.193	0.069	0.069
Total	**0.947**	**0.950**	**0.960**	0.960	**0.937**	**0.948**	**4.373**	0.951	0.970

Table 14. Mould cleaning process time observations (FLS-08).

The following outlines the timing for various tasks in the FLS-08 mould cleaning process across five observations, showing average, normal, and standard times. Mould Analysis is efficient, averaging 0.086 minutes. Air Pressure Cleaning takes 0.677 minutes on average, a bit longer but still within efficient limits. Cleaning by hand is quick at 0.128 minutes. Analysis Again has the lowest average at 0.057 minutes, indicating a thorough final review (table 14).

The total average time for all tasks is 0.948 minutes, with a normal time of 0.951 minutes, underscoring an efficient and consistent cleaning operation.

Coating/Painting									
Work Element	Observations of Time (min)					Average Time	PR	Normal Time	Standard Time
	1st	2nd	3rd	4th	5th				
Formation of Paint	2.35	-	-	-	-	2.35	-	-	2.35
1st Coat of Paint Brush	3.13	2.95	2.90	2.93	2.98	2.97	1.08	2.75	2.75
2nd Coat of Paint Brush	0.44	0.49	0.47	0.45	0.46	0.46	1.20	0.55	0.55
Spraying of Paint	0.35	0.389	0.375	0.384	0.40	0.38	1.10	0.35	0.38
Coating Inspection	0.12	0.10	0.10	0.11	0.13	0.11	1.09	0.11	0.12
Total	6.39	3.92	3.84	3.87	3.97	6.27	4.47	3.76	6.15

Table 15. Coating and painting process time observation (FLS-08).

Details about the time taken for each step in the coating and painting process, showing averages, performance ratings, normal times, and standard times. Painting Formation is the quickest task, averaging 2.35 minutes.

Applying the 1st Coat with a Brush takes longer, averaging 2.97 minutes, indicating higher complexity 2nd Coat Application and Paint Spraying times vary more, with averages of 0.46 and 0.36 minutes, respectively. Inspection of Coating is very fast, taking just 0.11 minutes on average, as demonstrated in (table 15).

Firing									
Work Element	**Observations of Time (min)**					**Average time**	**PR**	**Normal Time**	**Standard Time**
	1st	**2nd**	**3rd**	**4th**	**5th**				
Torch Bringing	4.22	4.15	4.24	4.30	4.48	4.27	1.08	4.27	4.62
Firing	26.14	27.25	26.98	26.50	27.56	26.88	1.06	26.88	28.46
Analysis	3.28	3.22	3.79	5.55	3.44	3.85	1.20	3.21	3.85
Firing (additional required)	-	-	2.35	-	2.46	2.40	1.04	2.31	2.40
Total	**33.64**	**34.62**	**37.36**	**36.35**	**37.94**	**37.40**	**4.38**	**36.67**	**39.33**
Pallette Shifting									
X-Y Crane Operation	1.2	1.4	1.2	1.1	0.93	1.16	1.42	1.65	1.65
Core Fitting									
Bringing of Cores	1.01	1.09	1.22	1.12	1.02	1.09	1.18	1.28	1.28
Adjusting of Core	2.74	2.65	2.80	3.06	2.88	2.82	1.13	2.50	2.50
Placement of Core (time/core)	3.11	3.30	3.28	3.50	3.40	3.31	1.12	2.96	2.96
Minor Adjustments	-	1.44	-	1.25	-	1.34	1.16	1.34	1.56
Analysis of mould with core on MNQ	15.22	15.15	15.13	15.14	15.17	15.16	1.03	15.16	15.61
Total	**22.08**	**23.63**	**22.43**	**24.07**	**22.47**	**23.72**	**5.62**	**23.24**	**23.91**

Table 16. Firing process time observations (FLS-08).

The following provides timing data for key tasks in the FLS-08 production line, covering firing, pallet shifting, and core fitting. In Firing, "Torch Bringing" averages 4.27 minutes, with a performance rating of 1.08, showing efficiency. The "Firing" task itself is more time-intensive, averaging 26.88 minutes, making this phase a priority for productivity improvements. The total firing time reaches 37.40 minutes, indicating its importance in the overall workflow. Palette Shifting is efficient, with the X-Y Crane averaging 1.16 minutes, suggesting a smooth material handling process (table 16).

In Core Fitting, "Bringing of Core" and "Adjusting of Core" are quick, averaging 1.09 and 2.88 minutes. However, "Analysis of Mould with Core on MNQ" averages 15.16 minutes, highlighting a potential area for streamlining.
This data underscores both strengths and potential improvement areas in the FLS-08 process, particularly for time-intensive tasks where optimization could enhance productivity.

Fettling									
Work Element	Observations of Time (min)					Average time	PR	Normal Time	Standard Time
	1st	2nd	3rd	4th	5th				
Reclamation Unit	62	62	58	56	58	59.2	1.14	67.48	77.61
Head Cutting	6.45	6.33	6.94	6.23	6.56	6.50	1.12	7.28	8.37
Grinding	23	21	22	25	24	23	1.19	27.37	31.47
Pin Grinding	42	43	42	44	40	42.2	1.09	46.99	54.04
Cosmetic	12	11	13	12.5	13.5	12.4	1.44	17.85	20.53

Table 17. Fettling process time observations (FLS-08).

As shown (table 17) it provides observations of time for fettling tasks in the FLS-08 production process, including averages, performance ratings (PR), and standard times for each element. The reclamation Unit has the longest average time at 59.2 minutes with a PR of 1.14, indicating slightly better than standard performance. Head Cutting averages 6.50 minutes with a PR of 1.12, reflecting consistent efficiency. Grinding and Pin Grinding take 23 and 42.2 minutes on average, respectively, with Pin Grinding suggesting room for efficiency gains. Cosmetic Work is the quickest task, averaging 17.85 minutes, indicating a well-optimized process.

The data shows varying efficiencies across tasks, pointing to areas where time management and productivity could be further improved.

12 Cupola furnace

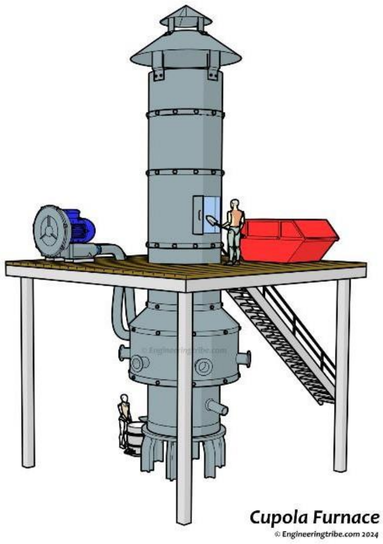


Figure1.Cupola device.

Cupola Device is a melting material, mainly used in factories to melt cast iron from pig iron. These iron types consist of pig iron, coke, limestone (flux) and scrap iron. The word cupola stands for “small dome” as meaning. As the name refers to it resembles its design and structure. The cupola is designed in a big vertical shape and has a tapping spout on the top (figure 1). (Engg-tribe, 2024)

Cupola analysis report

Cupola Process Breakdown

Cupola Preparation:

- 1-Day pit cleaning
- 1-Day line removal
- 3-day refractory line making
- 1-day ladle making, setting of the bed, and making of the hole.
- Firing Cupola

Operation Performed:

- Capacity in Tonnage

13 Workforce Analysis

A representation of the current workforce analysis for the Masonry and Helpers categories within the Qadri Group (table 18).

Present		
Strength	**Position**	**Skills**
Masonry (3)		
1	Supervisor. Sr Cupola Man (Head Meason)	Highly Skilled
2	Sr. Cupola Man	Moderately Skilled
Helpers (5)		
3	Jr. Cupola Man	Minimally Skilled
2	General Helpers	Minimally Skilled
Daily Wager		
1	Helper	Minimally Skilled+Illiterate

Table 18. Workforce distribution skills in the cupola.

It shows that there are three positions in the Masonry section, indicating a building in which one Supervisor is highly skilled, and the other Sr. Cupola Man has average skills. In contrast, the Helpers category includes two Jr. Cupola Men and general helpers, all of whom are rated as minimally skilled. In addition, there is one daily wager, simply known as a Helper, who is both marginally skilled and uneducated. This distribution indicates a substantial reliance on qualified workers in supervisory jobs, while the remainder of the workforce has minimal capabilities, which may indicate a need for additional training and development to improve total workforce competency.

Work hours

- Peak season = 8 Regular + 4 Overtime (Average)
  However, this plan varies from employee to employee.
- Off Peak season = 8 Regular

Suggestions

- The entire team shall be divided into two groups or shifts working regular hours without any additional overtime.
- Before this change, employees were typically working 12 hours daily, including an extra shift of 4 hours which led to a decrease in their productivity to approximately 60% by the end of their shift.
- By implementing a schedule of two shifts making a total of 16 hours, each shift will include 16 hours for rest. This arrangement will enhance the productivity of workers.
- To achieve this, it is necessary to provide training during the off-season to improve the skills of support staff to a moderate level.
- Previously, the group consisted of 8 workers and 1 daily wager. Currently, the updated count should be 10. To achieve this, we need to bring in 1 daily wager and 1 new recruit to the team.

The division of the teams will be as follows:
Cupola Lining Team = 2 (mason + assistant)

Other tasks = 3 (mason + 2 Senior cupola workers)

Strength	Position	Skills
1	Supervisor. Sr Cupola Man (Head Meason)	Highly Skilled
1	Senior Cupola Man (Mason)	Moderately Skilled
2	Junior Cupola Man	Minimally Skilled
1	General Helpers	Minimally Skilled

Table 19. Workforce strength and skills distribution.

The following shows the distribution of labour skills in Qadri Group's cupola activities. It demonstrates that the Supervisor Sr Cupola Man (Head Meason) has the greatest skill required, emphasizing the significance of this position. The Senior Cupola Man follows with moderate skill levels, needing experience and understanding but not the greatest proficiency. The Junior Cupola Man, with a strength of two, is classed as slightly skilled, indicating that extra training is required to increase performance. Similarly, General Helpers, who have a strength of one and are classified as minimally skilled, provide basic support for more skilled professions (table 19). However, these findings show the diversity of skill levels throughout the workforce and emphasize the need for training programs aimed at strengthening the skills of less experienced.

14 Qualitative and quantitative analysis results

Upon conducting a thorough analysis of the workforce, a suggestion was given for the differences in the workforce, the associated skills, comparisons concerning the workforce's strength, age demographics and literacy levels. The tables and graphs below illustrate the differences between the existing and the suggested strengths, skills, literacy, and age demographics.

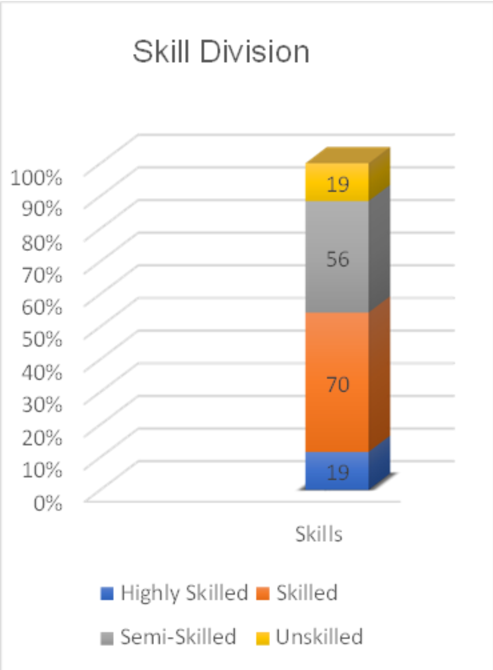
		Current								Suggested				
Strength		Skills						Annual	Need	Skills				
Perma-nent	Ctr	DW	Highly Skilled	Skilled	Semi Skilled	Un-skilled		Perma-nent	Ctr	DW	Highly	Skilled	Semi Skilled	Un-skilled
40	0	9	5	16	18	10	Cupola	34	6	10	8	18	16	8
65	2	8	7	30	30	8	HFF	70	12	6	10	36	36	6
38	0	2	7	24	8	1	Maintenance	39	0	1	6	25	7	2
143	**2**	**19**	**19**	**70**	**56**	**19**	**Total**	**143**	**18**	**17**	**24**	**79**	**59**	**16**
164									**178**					

Table 20. Current and proposed workforce strength and skill distribution.

As Provided in (table 20) it demonstrate a thorough overview of the current and proposed labour strength and skill distribution across three divisions: Cupola, HFF, and Maintenance. The current total workforce strength is 164, with 143 permanent employees and varied amounts of contract (Ctr) and daily wage (DW) workers. The skill distribution shows that a major share of the workforce is semi-skilled (56 individuals), with fewer highly skilled (19) and unskilled workers (19).
The proposed workforce strength rises to 178, reflecting a strategic initiative to enhance the number of highly skilled employees, particularly in the Cupola and Maintenance divisions, to meet future demands. The overall number of highly skilled workers is expected to increase from 19 currently to 34 under the proposed strategy. This increase is intended to improve operational efficiency and productivity, ensuring that the staff is better prepared to face the difficulties of the production process. The suggested changes emphasize a proactive approach to workforce management, including resolving skill shortages and aligning personnel capabilities with operational requirements.

14.1 Qadcast Division

The following Figures show that the workforce is divided into four primary groups based on their skills, age, literacy, and physical strength.



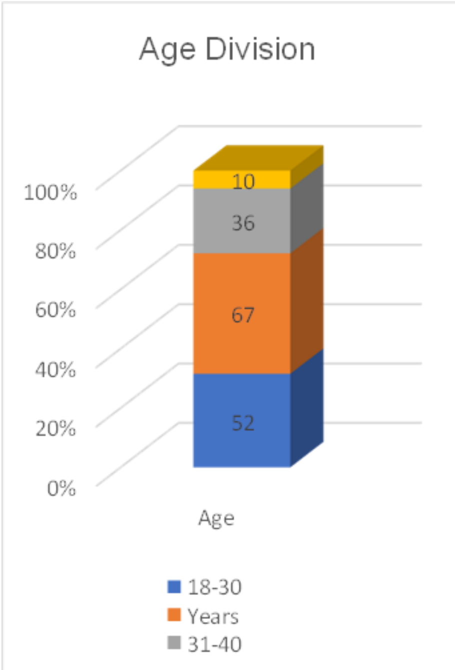
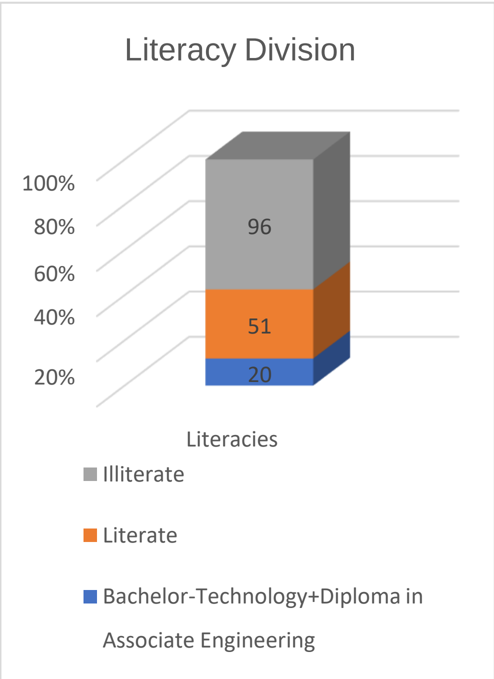


Figure 2. Workforce skill division   Figure 3. Workforce age division

The Skill Division shows that most of the workforce is classified as "Skilled," with a considerable number also labelled as "Highly Skilled" and a smaller group identified as "Unskilled." This indicates a workforce that is well-equipped with the necessary skills, which is vital for smooth operations (figure 2).

The Age Division points out a large number of employees in the 31-40 age range, indicating a workforce that is likely to have a lot of experience. The inclusion of younger employees (18-30 years) suggests the possibility of future expansion and skill enhancement within the Qadri group (figure 3).



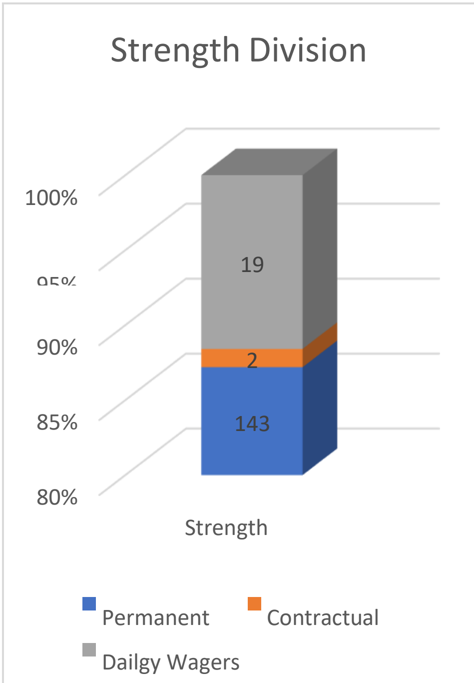


Figure 4. Workforce literacy division. Figure 5. Workforce strength division.

The Literacy Division highlights a mostly literate workforce, which is essential for clear communication and effective training. The small number of illiterate workers points out a potential area for improvement in how the company recruits and trains its employees (figure 4)

The Strength Division shows a mix of permanent, temporary, and daily wage workers. The greater number of permanent workers suggests stability, while the presence of temporary workers provides the company with the flexibility to adjust its workforce size during busy peak periods (figure 5).

Skill definition

- Highly Skilled (have the ability to create solutions, Supervise, lead and Train Others)
- Skilled (Can work Independently Operate & Guide Others)
- Semiskilled (Can work with a little bit of supervision)
- Unskilled (Cannot operate on their own / Requires significant supervision)

14.2 Skill-to-Strength Comparison

As seen in (figure 6) it shows the difference between present and suggested labour skill levels in different areas. The "Highly Skilled" category presently has a strength of 19, which falls short of the recommended 24.

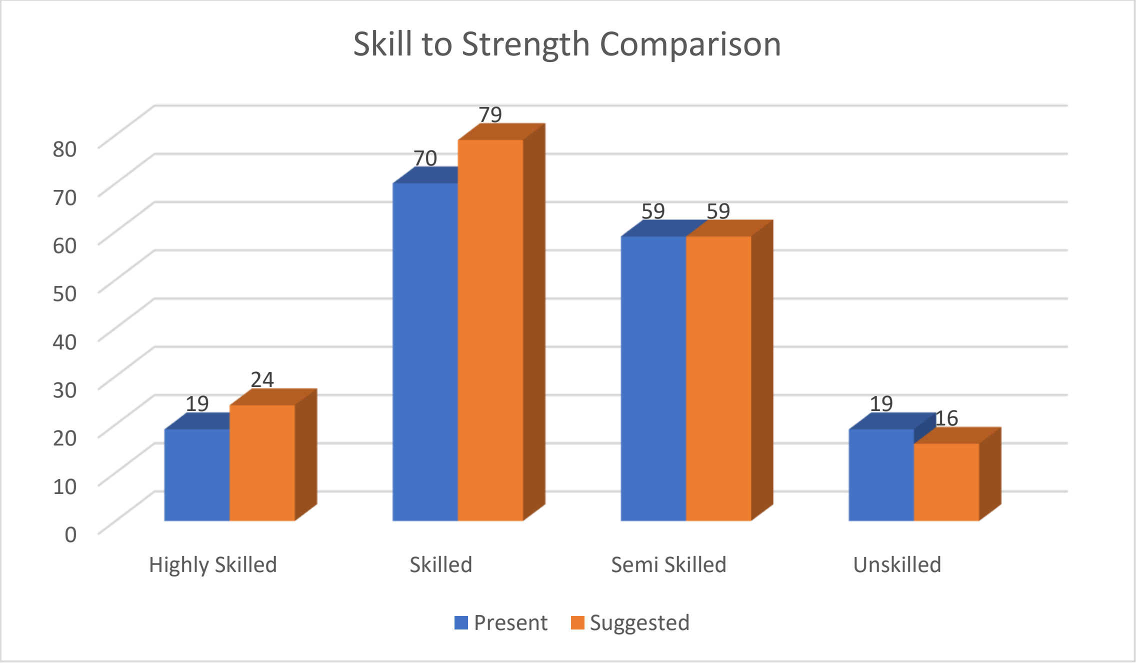


Figure 6. Workforce skill to strength comparison.

Additionally, the "Skilled" category has a current strength of 70, which is near the recommended 79. The "Semi-Skilled" category is constant, with current and proposed strengths of 59. However, the "Unskilled" group has a current strength of 19, compared to the required 16.

The research emphasizes the importance of improving the highly trained workforce, which is where the biggest gap exists. It suggests a strategic focus on increasing employee abilities in order to better fit with future labour requirements.

14.3 Strength to literacy comparison

Present

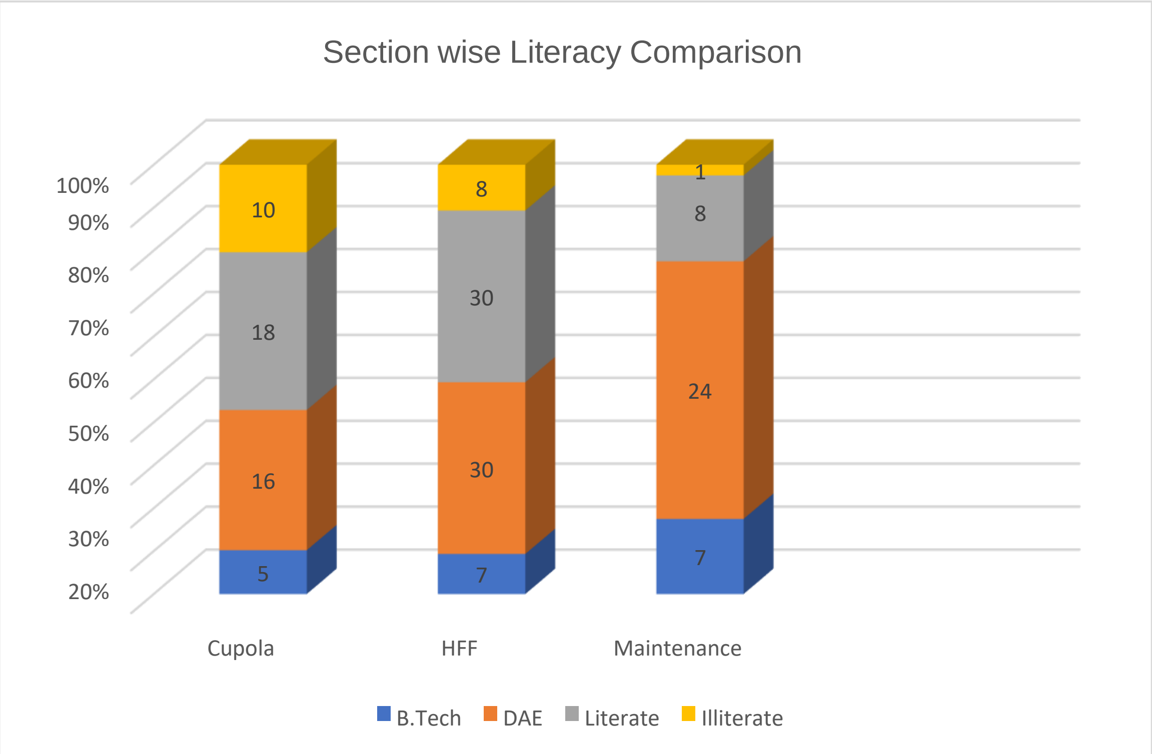


Figure 7. Workforce present, section-wise literacy comparison.

Details of the current literacy levels of employees in the Cupola, HFF, and Maintenance sectors, organized by qualifications such as B.Tech, DAE, Literate, and Illiterate. The Cupola department leads with 10 people with B.Tech degrees, whereas HFF has a large number of DAE-qualified personnel (30) are illustrated in (figure 7). However, the Maintenance division has a wide range of qualifications but also includes seven illiterate individuals. This report emphasizes the workforce's diverse educational backgrounds and the need for focused training initiatives to increase skill levels across all sections.

Suggested

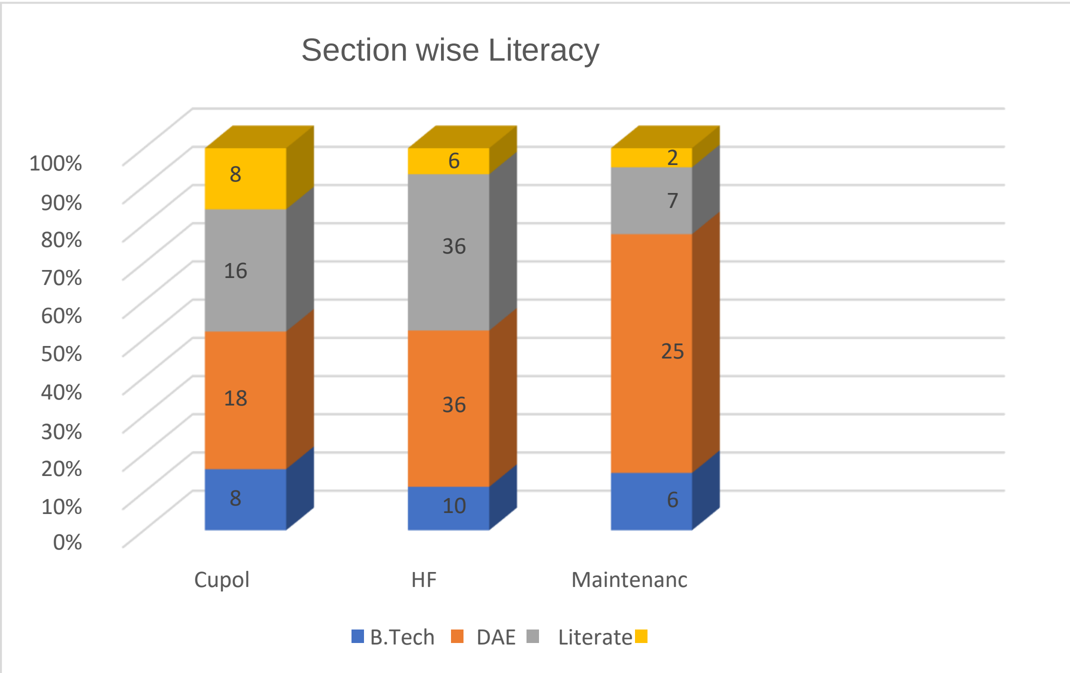


Figure 8. Suggested workforce section wise literacy.

In the proposed scenario, all sections show improvements in literacy. The Cupola section's rate increases slightly, the HFF section rises to 36%, and the Maintenance section also experiences a positive trend (figure 8). This data indicates that implementing targeted training and hiring strategies could effectively boost literacy levels, enhancing overall workforce capability and efficiency.

14.4 Strength to age comparison

Present Strength Age

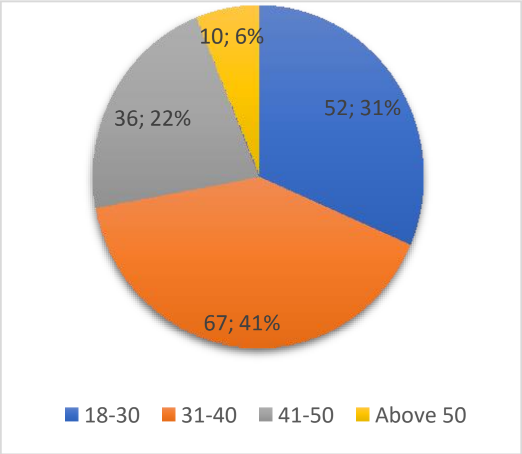


Figure 9. Present workforce strength Age

Suggested Strength age

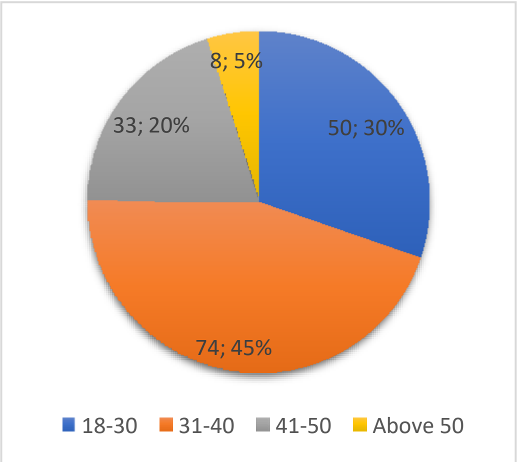


Figure10.Suggested workforce strength Age

Demonstration of remarkable differences in age distributions between the current and proposed workforce strengths. Currently, the 18-30 age group comprises 52 individuals, or 41% of the total workforce, while those aged 31-40 account for 67 individuals (41%). Older age groups (41-50 and above 50) make up 22% and 6%, respectively, indicating a potential risk of skill drain as the workforce ages (figure 9)

In the suggested distribution, the 18-30 age group increases to 50 individuals, representing 30% of the workforce. The 31-40 age group increases to 45%, while the proportions of older workers remain stable. This change suggests a strategy to refresh the workforce, promoting a balance that could improve operational efficiency and adaptability in the future (figure 10).

15 Ergonomics study-fettling section


Picture 1. Fettling section overview Picture 2. Fettling workstation condition

A current image of the working environment in the fettling department, emphasizing the current state of ergonomics can be seen in (picture 1). The workspace is messy, with waste and materials all over the floor. This disorder creates possible dangers that could result in worker accidents or injuries, underlining the importance of improving ergonomic standards. Furthermore, the existence of safety signage indicates an understanding of safety rules, but the physical environment may impede compliance. Addressing these concerns may improve worker safety and productivity.

The workstation in the fettling section is congested. Which is causing ergonomic danger to the workers. The worker was pictured bending over in a position that could cause strain and discomfort over time (picture 2). The appearance of scattered tools and materials implies a lack of organization, which might increase the danger of damage. Improving the structure and cleanliness of the workplace may considerably improve worker safety and efficiency, lowering the risk of musculoskeletal illnesses. Implementing basic ergonomic practices, such as keeping a clean workspace and making tools conveniently accessible, would encourage better posture and overall well-being among employees in this environment.

Picture 3. Worker performing fettling operations.

Picture 4. Worker fettling process workstation.

A worker performing fettling operations and wearing personal protective equipment (PPE) for safety (picture 3). The picture underlines the necessity of ergonomic considerations in the workplace, including the worker's posture and the layout of the workspace.

The worker's posture raises worries about the possibility of musculoskeletal disorders (MSDs) if ergonomic standards are not followed correctly. To support a natural posture, the workstation should be designed to minimize strain by making equipment and materials easily available. While the use of PPE demonstrates compliance with safety regulations, ongoing evaluations and adjustments to the work environment are required to increase worker comfort and productivity while minimizing the risk of injury.

A worker engaged in the fettling process, which is a critical manufacturing step in which excess material is removed from castings to produce the appropriate form and last form. The worker is stationed at a well-equipped workstation and takes a systematic approach to the activity.
The manufacturing environment is quite busy, with a mix of raw materials and finished goods (picture 4). The worker's use of personal protective equipment (PPE), which includes gloves and a mask, emphasizes the significance of safety standards in reducing injury risk and protecting against exposure to dust and other hazardous substances.

15.1 Rapid entire body assessment (REBA)

Rapid entire body assessment (REBA). This ergonomic assessment method evaluates the whole body postural Musculoskeletal Disorder (MSD) and the obstacles related to the job task. A page worksheet can be used to evaluate a specific body part or more if required, movement type, Coupling, and force applied. Rapid Entire body Assessments (REBA), using the REBA worksheet, the examinator can give a score to each of the following body parts: neck, trunk, lower arm, upper arm, force loads and legs. (kamble & Kulkarni, 2014). This evaluation will enable Qadri Engineering to well maintain their workers to keep the right posture whenever performing a task.

15.2 REBA Analysis

Task Report 1

Department	QHSE
Task 1	**Risk Assessment**
Risk Overview	
Initial Risk Index	3.75
Initial Assessment	
Rapid Entire Body Assessment	
Risk Index	3.75
Neck	2
Trunk	4
Legs	4
Force Load	1
Upper Arm	3
Lower Arm	1
Assessment Result	
Total REBA Score	15

Table 21. REBA Report analysis (task1).

REBA analysis for the QHSE department illustrates an Initial Risk Index of 3.75, showing a medium level of risk associated with the assessed task. The Rapid Entire Body Assessment confirms this with the same Risk Index value. The breakdown of specific body parts indicates that the neck and lower arm are at lower risk levels (scores of 2 and 3, respectively), while the trunk and legs have higher scores of 4, suggesting a greater risk illustrated in (table 21). The overall Total REBA Score of 15 signifies a very high risk, which requires immediate attention and corrective actions to mitigate potential musculoskeletal disorders among workers.

Task Report 2

Department	QHSE
Task 2	Risk Assessment
Risk Overview	
Initial Risk Index	3.75
Initial Assessment	
Rapid Entire Body Assessment	
Risk Index	3.75
Neck	4
Trunk	4
Legs	3
Force Load	1
Upper Arm	2
Lower Arm	1
Assessment Result	
Total REBA Score	15

Table 22. REBA Report analysis (task 2).

The REBA (Rapid Entire Body Assessment) results for Task 2 in the QHSE department, produced a total score of 15. This score indicates a very high level of risk, necessitating prompt action to reduce the likelihood of workers developing musculoskeletal disorders (MSDs). The examination identifies particular risk factors, with the trunk and neck rating the highest (4 each). These findings indicate that existing working conditions may risk safety, particularly for the trunk and neck, emphasizing the critical need for ergonomic interventions (table 22).

Task Report 3

Department	QHSE	
Task 3	Risk Assessment	
Risk Overview		
Initial Risk Index		2.75
Initial Assessment		
Rapid Entire Body Assessment		
Risk Index		2.75
Neck		2
Trunk		2
Legs		1
Force Load		2
Upper Arm		3
Lower Arm		1
Assessment Result		
Total REBA Score		11

Table 23. REBA Report analysis (task 3).

As revealed (table 23) the task has an initial risk index of 2.75, indicating a modest risk level. The Rapid Entire Body Assessment similarly produces a risk index of 2.75, indicating consistency in risk evaluation. The assessment of particular body parts reveals that the neck and trunk score 2, whereas the legs and lower arm score 1. The upper arm had a score of 3, indicating higher danger in that area. The total REBA score of 11 indicates a very high-risk level, highlighting the need for rapid intervention to improve ergonomic conditions and limit the possibility of musculoskeletal problems.

Task Report 4

Department QHSE	
Task 4 Risk Assessment	
Risk Overview	
Initial Risk Index	2.75
Initial Assessment	
Rapid Entire Body Assessment	
Risk Index	2.75
Neck	2
Trunk	3
Legs	1
Force Load	1
Upper Arm	3
Lower Arm	1
Assessment Result	
Total REBA Score	11

Table 24. REBA Report analysis (task 4).

A result of REBA (Rapid Entire Body Assessment) score of 11 for Task 4 in the QHSE department, indicates a high level of risk and the need for immediate corrective action. Initially, the risk was graded moderately with an Index of 2.75, but the REBA assessment raises specific concerns. The trunk score of 3 indicates significant postural difficulties, while the neck and lower arm scores of 2 and 1 indicate additional areas for concern (table 24).

These findings show the need for ergonomic changes in reducing musculoskeletal risk in this task.

Score	Level of MSD Risk
1	negligible risk, no action required
2-3	low risk, change may be needed
4-7	medium risk, further investigation, change soon
8-10	high risk, investigate and implement change
11+	very high risk, implement change

Table 25. Overview of musculoskeletal disorder (MSD) risk levels.

As Illustrated in (table 25) Musculoskeletal Disorder (MSD) risk levels using scored evaluations. The scores range from 1 to over 11, with each value representing the level of activity required. A score of 1 indicates insignificant risk and requires no action, although scores of 2-3 indicate low danger and may warrant modifications. Scores ranging from 4 to 7 suggest a medium risk that requires additional research, but scores of 8 to 10 indicate a high risk that necessitates rapid inquiry and execution of adjustments. Finally, a score of 11 or greater indicates a very high risk, requiring immediate action to enact modifications to address any health risks. This organized method enables firms to prioritize and effectively handle ergonomic concerns.

After Conducting the REBA analysis for 4 employees, it is concluded that the REBA total score is very high for all 4 of them and this is explained in the table above what it means to have a high REBA score. The target for the REBA assessment is a score of 4 (ergo-plus, 2024, 18).

16 Costs associated with QadCast

These include the expenses related to employee wages due to differences in their physical abilities.

QadCast									
	Strength			Permanent		Contractor		Daily Wagers	
	Per manent	Contr- actor	DW	Per Month	Annual	Per Month	Annual	Per Month	Annual
Average Salary (Euro)				121.95	1463.41	90	1080	92.63	1111.58
Present Strength (Euro)	164	2	19	20000	240000	180	2160	1760	21120
Proposed Strength (Euro)	178	18	17	21707	260484	1620	19440	1577	18924
Difference (Euro)				1707	20484	1440	17280	-183	-2196

Table 26. Employee wage expenses at Qadcast.

Information of QadCast's employee wage expenses, broken down by employee category and number. Permanent employees currently earn an average salary of €121.95, for a total of €1,463.41 per year. The monthly and annual costs for 164 permanent staff are €20,000 and €240,000, respectively. The projected increase to 178 personnel brings these expenditures to €21,707 monthly and €260,484 yearly, representing a €1,707 cost increase for permanent employees. Contractor and daily wage expenses vary, with a €2,196 reduction in daily labour costs (table 26). This data demonstrates the fiscal impact of workforce changes, emphasizing the significance of strategic workforce planning.

Cost Analysis Fettling Cost (Euros)

Manufacturing Cost with Machining (including Pattern, Packing, Transportation) for FLS-19 Hammer= €1.30/ kg

Manufacturing Cost with Machining (including Pattern, Packing, Transport) for FLS-08 Grate Plate= € 3.5/kg

Costs involved in previous one year(existing costs)

In previous 1-year dispatched FLS-19 Hammers = (30 × 100 kg) + (46 × 99 kg) + (46 × 100 kg)

=3000 kg + 4554 kg + 4600 kg

=12154 kg

Cost Involved = 12154 kg × € 1.30/kg

= € 15800.2

In previous 1-year dispatched FLS-08 Grate Plates = (195 × 25 kg) + (95 × 26 kg) + (55 × 26 kg)

=4875 kg + 2470 kg + 1430 kg

= 8775 kg

Cost Involved= 8775 kg × € 3.5 / kg

= € 30712.5

Total Sales Costs Involved= € 15800.2 + € 30712.5

= € 46512.7

Predicted Costs for the next 1 Year (16 New Labour with 70 %efficiency)

If newly trained contractors produce 70% efficiency, then FLS-19 Hammers Produced= (12154) ×(70/100)

= 8507.8 kg

Cost Involved= 8507.8 kg × € 1.30 / kg

= € 11060.14

If newly trained contractors produce 70% efficiency, then FLS-08 Grate Plates Produced = (8775 kg)× (70/100)

= 6142.5 kg

Cost Involved= 6142.5 kg × € 3.5/ kg

= € 21498.75

Total Sales Costs Involved= € 11060.14 + € 21498.75

= € 32558.89

Investment in newly Hired Worker's Salary

If, Average Cost of Labour = € 90

New Hired Contractual Workers = 16										
Training Period of New Labours = 6 months										
Salary Paid to 16 Workers for 6 months = € 90 × 16 × 6										
= € 6480										

Table 27. Cost analysis for fettling comparison of previous and future costs for producing (FLS-19 hammers and FLS-08 Grate plate).

A representation of a cost analysis of fettling at Qadri Group, comparing historical and future costs for producing FLS-19 Hammers and FLS-08 Grate Plates is demonstrated in (table 27). The data indicates significant labour and material expenses from the previous year, as well as projected costs for next year with 16 new labourers operating at 70% efficiency. This analysis emphasizes the need for good labour cost management in improving productivity and profitability, with expected savings achieved through increased worker efficiency.

17 Conclusion

It is well known that the foundry is the primary source of revenue for the Qadri Group of Companies, thus the processes and activities carried out here are vital and unique. Upon conducting the calculations at QadCast, It is concluded that skill drainage is one of the most important aspects and ground realities on the production floor. Additionally, this needs to be addressed by creating training pools and shared assistance pools. The quantitative aspects demonstrate the optimal worker strength required during peak and off-peak seasons to achieve maximum efficiency and productivity.

18 Future to-do’s QadCast

1. To employ an Industrial Engineer expert for a full-time position to conduct comprehensive work and motion studies, as well as carry out direct time studies. This will enhance and refine the process, thereby increasing worker's efficiency and productivity, which will lead to more orders from marketing.
2. To conduct an Ergonomics study aimed at enhancing the efficiency of workers by improving the poster and reducing their risk index.
3. To address issues with casting defects to minimize the workload on the fettlers.
4. To implement quality assurance measures at the mould closure stage to eliminate defects in casting.
5. To introduce a semi-automated fettling line to boost the efficiency of the fettling process.
6. To develop talent pools (investments in skills) to address the skill drain for future needs.
7. To establish a policy for incentive wages during peak labour periods.
8. To create a pool of helpers to mitigate skill drain, absenteeism, and manage workload.
9. To implement a Preventive Maintenance Initiative: Regular monitoring of machinery, can avoid unexpected failures, minimizing interruptions and guaranteeing more consistent production processes. This approach will boost efficiency, give more lasting time to the equipment and enable employees to work more effectively.
10. Start Continuous employee training programs: Providing continuous learning and safety instruction will keep employees up to date with the latest methods or practices. This will not only increase productivity but also decrease mistakes and incidents, leading to better efficiency and a more secure work environment.

19 Calculation at Qadri Engineering's second unit

The Mill Bottom Roller Shaft and Bottom Roller Shell (Lotus Type) were chosen for calculations.

A Developed survey of worker’s questionnaires was conducted aiming to perform a time and motion study.

The following formulas were used:

- Machine-Hours (Hm) in QEN =20 hours/day
- Machine-Hours/ Unit = Number of hours operated/ Number of units produced (Q).
- Machine- Hour Rate= Factory Overheads/ Hm
- Man-Hours = Number of Workers × Number of hours each worker worked
- Productivity = Q/ Man-Hours

A Description of the Mill Bottom Roller Shaft activities, including time, machinery requirements, and worker skill levels. Operations range from 2 to 50 hours, with Final Turning taking the longest at 50 hours (table 28).

Mill Bottom Roller Shaft								
Operation	Time (hrs)	Machine	Workforce Suggested		Skill Proposed			Variance
			Day	Night	Highly Skilled	Skilled	Semi-Skilled	
Rough Centre	5	G&L Boring (M)	2	1	1	1	-	3-2
Rough Turning	20	DXW-2 (L)	1	1	-	1	1	2-2
True center	10	Poreba Lathe 1(L)	2	2	-	2	1	4-3
Final Turning	50	Poreba Lathe 1(L)	2	1	-	1	2	3-3
Marking of square	2	Marking table	1	1	1	1	-	2-2
Square Machining	12	Planer-1 (L)	2	1	-	2	1	3-3
Marking of keyway	3	Marking table	2	2	-	2	1	4-3
Keyway machining	25	Planer-1 (L)	2	1	1	2	-	3-3
Fitter work	5	Fitter section	1	1	-	1	1	2-2

Table 28. Mill bottom roller shaft activities operational breakdown.

Both day and night shifts necessitate a combination of highly skilled, skilled, and semi-skilled employees. A variance column reveals skill level disparities, which aids in the identification of training and optimization opportunities.

Bottom Roller Shell (Lotus Type)								
Operation	Time (hrs)	Machine	Workforce Suggested		Skill Proposed			Variance
			Day	Night	Highly Skilled	Skilled	Semi-Skilled	
Head part of shell	12	Froriep lathe (L)	1	2	1	2	-	3-3
Rough turning	3	Froriep lathe (L)	1	2	1	2	-	3-3
Boring shell	20	Shell boring QE (M)	2	2	-	2	1	4-3
Marking of drilling	2	Marking section	2	1	-	2	-	3-2
Drilling + Tapping	8	Drill machine-2 (S)	1	1	-	2	1	2-3
Shrink fit size ofshaft	16	Poreba lathe-1 (L)	2	1	1	-	1	3-2
Shrink fitting	12	Shrink fit furnace2	2	2	-	2	2	4-4
Final turning	20	Noble Lathe QE (L)	1	1	1	1	-	2-2
Marking of Grooving	3	Marking section	3	1	-	1	3	4-4
Rough Grooving	20	Noble Lathe QE (L)	2	2	-	2	2	4-4
Final Grooving	15	Noble Lathe QE (L)	1	1	-	1	1	2-2
Marking of nozzle drilling	3	Marking section	1	2	1	2	-	3-3
Nozzle drilling	91	CNC Ceruti (M)	1	1	-	3	1	2-4
Nozzle fitting	20	Fitter work 6	1	1	1	-	2	2-3
Fitter work of nozzle	20	Fitter work 6	3	1	-	2	1	4-3
Fitter work	10	Fitter work 6	2	1	-	1	2	3-3
TOTAL	**275**		**26**	**22**	**6**	**25**	**17**	**48-48**

Table 29. Bottom Roller Shell (Lotus Type) operational breakdown.

The operational breakdown for the Bottom Roller Shell (lotus type), including needed time, machine usage, personnel ideas, projected skill levels, and deviations (table 29). It comprises several processes, each with a specified time allocation, showing the manpower required for both day and night shifts. The variance column highlights the gap between the indicated and proposed skill levels, indicating areas where skill development may be required. Overall, total operational time is 275 hours, with changing worker demands across different jobs, showing a need for careful management of skills and resources to enhance production efficiency.

19.1 Machine hours vs man's hours

The data shown in Table 30 represent the planned and achieved machine hours for many machine families from January to June. It identifies considerable swings in efficiency rates, indicating operational issues in various months.

Machine Family	January			February			March		
	Capacity Planned	Capacity Achieved	Efficiency	Capacity Planned	Capacity Achieved	Efficiency	Capacity Planned	Capacity Achieved	Efficiency
Horizontal Lathe	9360	5030	54%	9360	5084	54%	9360	4487	48%
Floor Boring	7800	5454	70%	7280	3214	44%	7280	5016	67%
VL Lathe (Large)	3120	2872	92%	3120	1773	57%	3120	2456	79%
Planer	2080	1125	54%	2080	698	34%	2080	759	36%
Small Machine	6240	4100	66%	5720	3124	55%	5720	2798	47%
Hobbing	1560	638	41%	1560	1262	81%	1560	587	38%
Machine Family	**April**			**May**			**June**		
	capacity Planned	**Capacity Achieved**	**Efficiency**	**capacity Planned**	**Capacity Achieved**	**Efficiency**	**capacity Planned**	**Capacity Achieved**	**Efficiency**
Horizontal Lathe	9360	8223	88%	9360	9442	101%	9360	9922	106%
Floor Boring	7800	7891	101%	7280	8634	111%	7280	8725	112%
VL Lathe (Large)	3120	2996	96%	3120	3410	109%	3120	3457	111%
Planer	2080	1804	87%	2080	1682	81%	2080	1716	83%
Small Machine	6240	4908	79%	5720	5206	83%	5720	5487	88%
Hobbing	1560	240	15%	1560	401	26%	1560	0	0%

Table 30. Machine hours vs man's hours planned and achieved machine hours for various machines groups.

For example, the Horizontal Lathe has a consistent but low efficiency of roughly 54% in January and February, increasing to 61% in March, whereas the Floor

Boring machine family has a significant efficiency increase to 101% in April. This pattern indicates that certain months were more productive, most likely as a result of operational or workforce management modifications. Furthermore, the Small Machine family achieved lower capacity levels, particularly in June, when efficiency declined to 88%. Overall, this table demonstrates the importance of continuing to monitor and optimize equipment and workforce use in order to increase overall production.

19.2 Units produced data from the past 8 months

The Total Units Produced from 1st of January 2024 until 20th of August 2024 are = 4060 units. The Units produced by QEN include Shafts, Rollers, Shells Hammers, etc.

Month Name	Sugar	Non-Sugar	Total Units Produced
January	218	110	328
February	215	350	565
March	100	230	330
April	230	378	608
May	355	245	600
June	417	107	524
July	365	180	545
August	385	175	560
Total	**2285**	**1775**	**4060**

Table 31. Units produced data from the past 8 months' production statistics for sugar and non-sugar units.

A calculation of eight months of production statistics for sugar and non-sugar units, totalling 4,060 units (2,285 from sugar and 1,775 from non-sugar) (table 32). The month of June had the largest output at 524 units (417 sugar, 107 non-sugar), while March had the lowest at 330 units (100 sugar, 230 no sugar). These fluctuations highlight the importance of tracking production trends in order to better allocate resources and plan for them.

20 Quantitative and qualitative analysis results

Current							Area	Suggested						
Strength			Skills					Annual	Need		Skills			
Permanent	Ctr	DW	Highly	Skilled	Semi Skilled	Un-skilled		Permanent	Ctr	DW	Highly	Skilled	Semi Skilled	Un-skilled
60	2	2	6	46	12	0	Lathe	66	1	1	10	48	8	2
64	2	0	4	46	16	0	Boring	60	0	0	10	40	10	0
40	0	2	4	22	14	2	CNC	40	1	0	6	25	10	0
30	10	2	6	12	23	1	Fitters	28	9	1	6	12	20	0
125	6	20	20	52	61	18	Mainten-ance	123	8	18	18	52	60	19
319	20	26	40	178	126	21	Total	317	19	20	50	177	108	21

Table 32. Workforce composition based on employment type and skill level comparison of current and suggested workforce composition.

A comparison of the current and suggested workforce composition based on employment type (permanent, contractual, and daily wage) and skill level (highly skilled, semi-skilled, and unskilled) is illustrated in (table 32). Currently, the workforce totals 319, with a little reduction suggested to 317. Significant changes have been seen in the maintenance department, especially in skilled workers, reflecting a strategic focus on improving operational efficiency. Overall, the research underlines the significance of maximizing the workforce to align with business goals.

20.1 Skill comparison present vs proposed vs variance in propose

The following (Figure 11) compares present and proposed workforce skill levels, highlighting shifts in four categories: highly skilled, skilled, semi-skilled, and unskilled. The Highly Skilled group is projected to expand from 50 to 40, while Skilled workers will be cut from 178 to 177 in the plan.

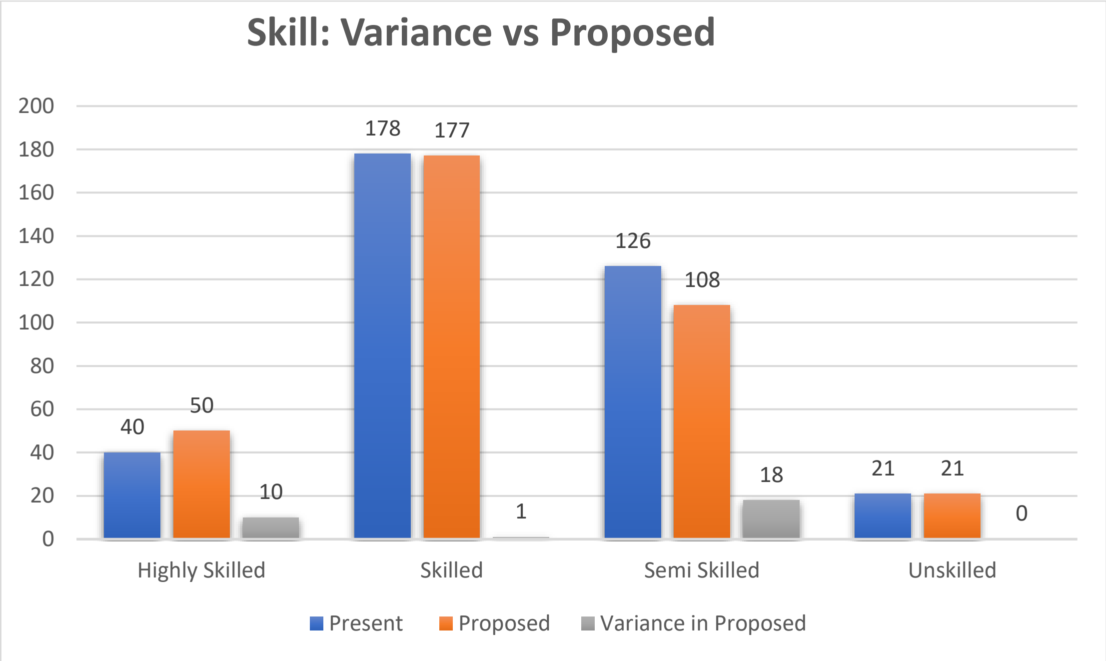


Figure 11. Workforce skill variance vs proposed.

The Semiskilled category is predicted to decline from 126 to 108, while the Unskilled category remains unchanged at 21. These changes reflect a strategic emphasis on improving skill distribution to increase operational efficiency.

20.2 Boring skill comparison present vs proposed vs variance

As shown (Figure 12). Below is a skill comparison for the boring line, showing current and proposed workforce levels by skill category. Highly skilled workers are steady at 4, while the skilled category shows a significant increase from 6 to 46, adding 40 positions.

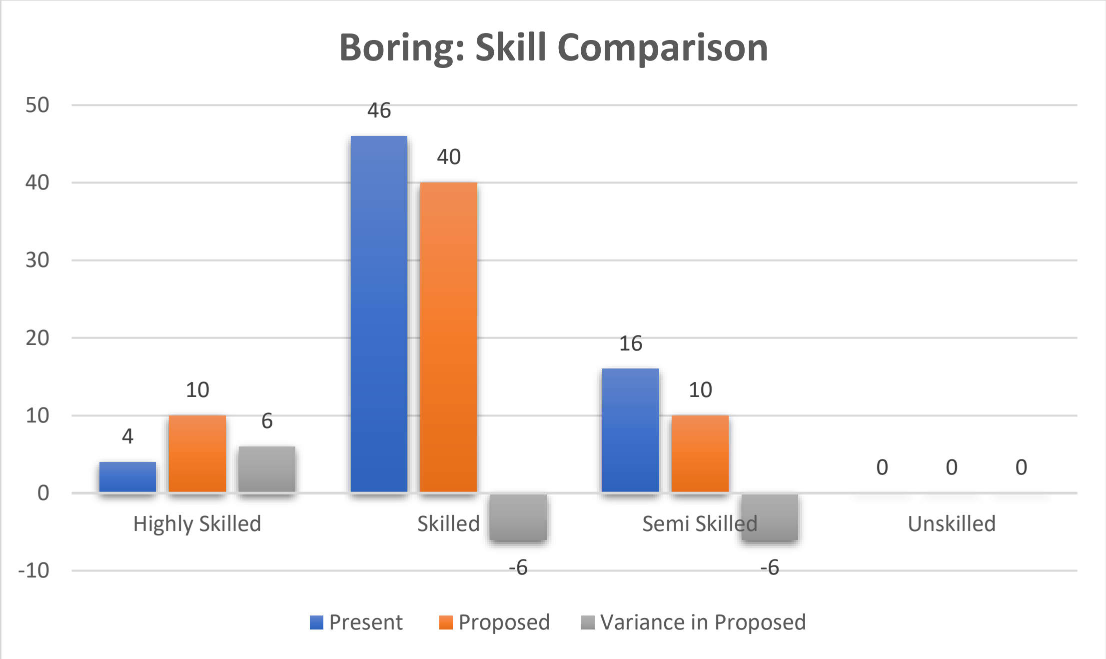


Figure 12. Workforce Boring skill comparison.

Semi-skilled occupations fall from 16 to 10, a reduction of 6, and unskilled positions remain at 0 in both situations. This figure emphasizes a focus on increasing the skilled workforce inside the boring line to maximize production.

20.3 Fitter skill comparison present vs proposed vs variance

As seen in (Figure 13). Below are the current and proposed skill levels in the fitter area, revealing that highly skilled remain at 6. Semi-skilled rose from 20 to 23, while the skilled group remained stable at 12.

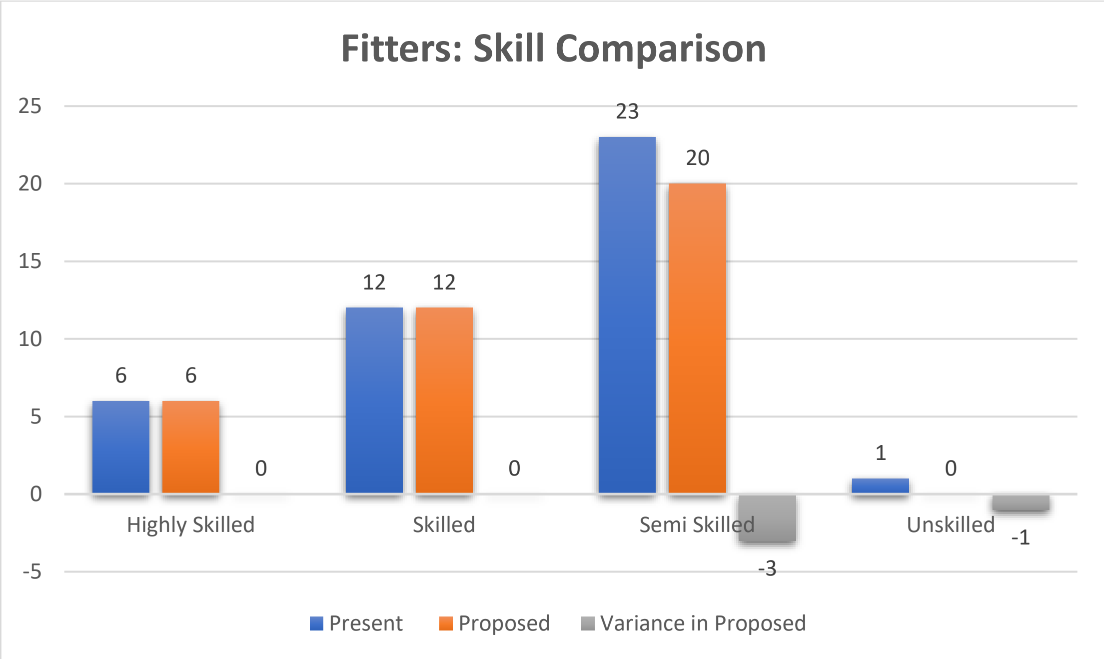


Figure 13. Workforce fitters skill comparison.

The unskilled group decreases slightly from 1 to 0. This change reflects a strategy to increase semi-skilled roles to better support operational demands.

20.4 Strength and literacy

An illustration of the labour distribution and literacy levels for the Lathe, Boring, CNC, and Fitter lines. The Lathe and Boring lines have the most employees, each with 46, while the CNC and Fitter lines have 22 and 23 people, respectively (figure 14).

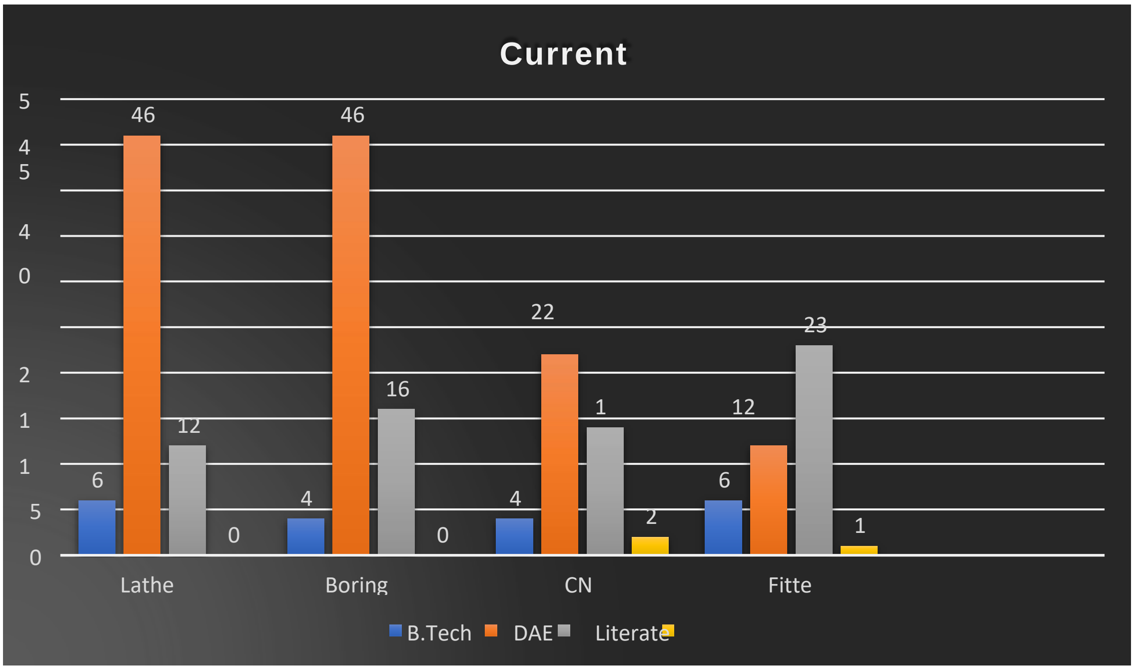


Figure 14. Workforce current strength and literacy

The Boring line has the most literate staff (16), while the CNC and Fitter lines have fewer (14 and 12). The Lathe and Boring lines have the most skilled qualifications (B.Tech. and DAE). This data reveals differences in staff literacy and qualifications, which affect operational efficiency and potential training needs.

The following (Figure 15). Displays the proposed worker composition by educational qualifications for the Lathe, Boring, CNC, and Fitter lines. The Lathe line has the highest proposed workforce of 48 personnel, with the majority being B. Tech and DAE-qualified, indicating a high skill level.

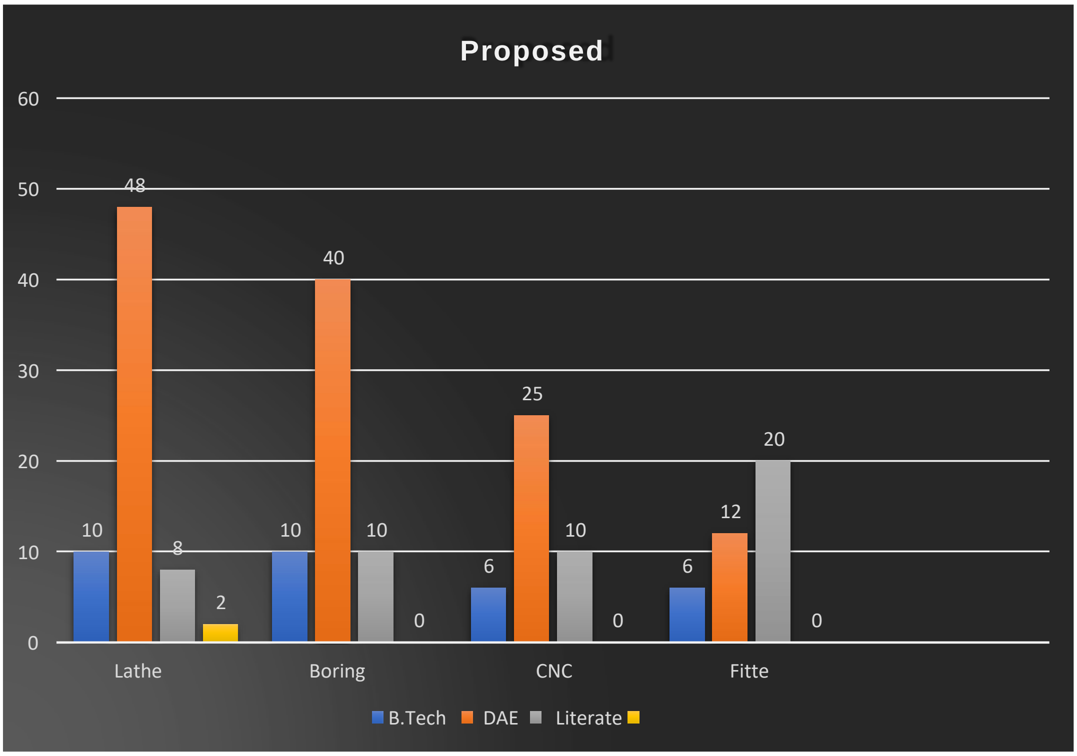


Figure 15. Workforce proposed strength and literacy

The Boring line follows with 40 workers, mostly B. Tech and DAE. The CNC line is expected to employ 25 people, the majority of whom will have DAE and literacy certificates, while the Fitter line will employ 20 people, many of whom are literate. This distribution shows a focus on improving skills, particularly in technical professions, in order to boost production and efficiency.

20.5 Strength and age demographics

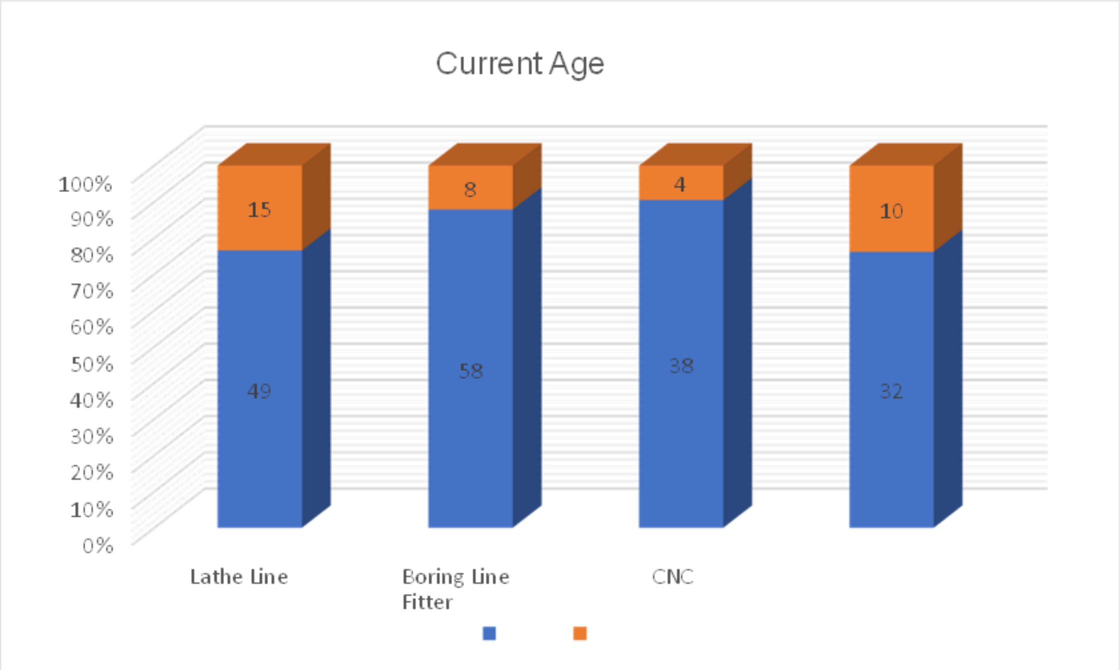


Figure 16. Current workforce age demographics

A Demonstration of the age distribution of employees at Qadri Group's production facility, which is separated into two age groups: 18-40 and 41-60 years (figure 16). The Lathe and Boring lines have younger personnel, with 49 and 58, respectively, while the CNC line has 32 older people, and the Fitter line has 10. This age distribution suggests that older personnel, particularly those in the CNC and Fitter lines, require retention and skill development measures to preserve competence and continuity in the manufacturing process.

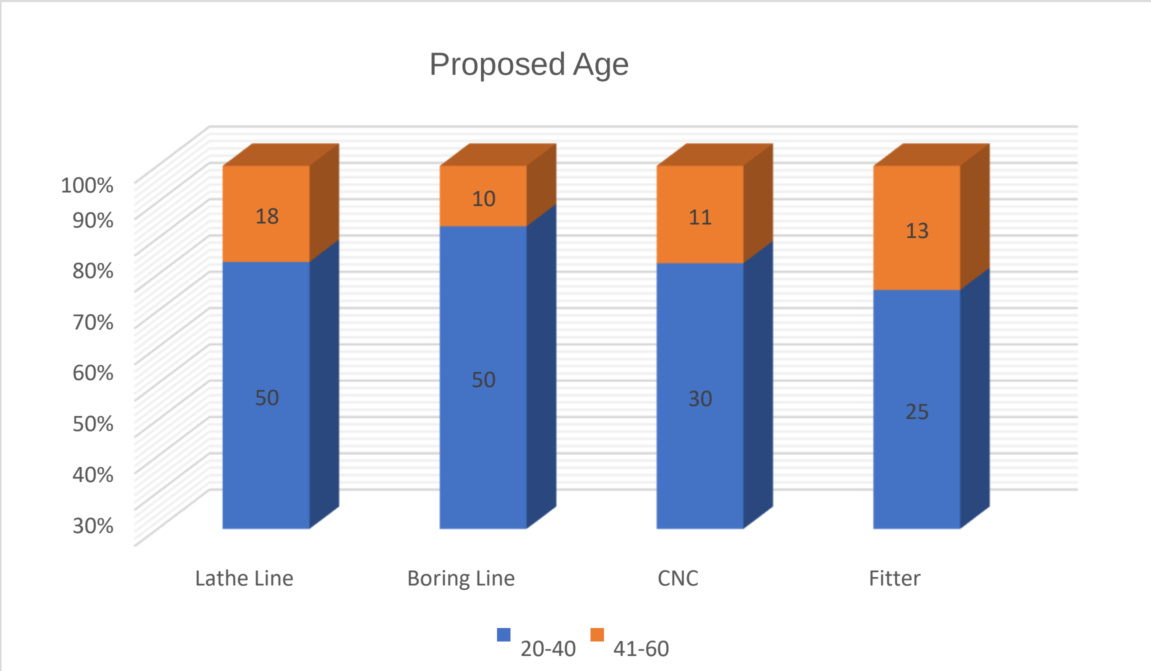


Figure 17. proposed workforce age demographics distribution for workforce improvement.

The following shows the proposed age demographics for the Lathe, Boring, CNC, and Fitter lines, with employees divided into two age groups: 20-40 (represented in blue) and 41-60 (represented in orange). The Lathe Line employs a large number of younger workers, with 50 individuals aged 20 to 40, compared to 18 on the Boring Line. The CNC line has 30 younger personnel, whereas the Fitter line has a balanced age distribution, with 25 in the younger category (figure 17). This emphasis on younger staff reflects a strategy move toward increased productivity and adaptability, potentially improving efficiency across production lines.

21 Training pool model

As described in (table 33) a training program for present Qadri Engineering employees, includes the credentials of trainers based on skills, age, experience, and role. Trainers are often highly trained professionals over the age of 45 with more than ten years of experience and serve as Supervisors or Senior Workers.

Training of Current Workers					
	Skills	**Age**	**Experience**	**Position**	**Employees Ranking**
Trainer	Highly Skilled	> 45	> 10 Years	Supervisor, Senior Worker	N4, N5
	Trainers			Training Period	
Suggested Section	Lathe Line: Supervisor and the men in charge			6 months training period in Off-peak season	
	Boring Line: Supervisor and the men in charge				
	CNC Line: Supervisor and the men in charge				
	Fitters Section: Supervisor and the men incharge				

Table 33. Training program for present employees overview

The proposed training focuses on supervisors and team leaders for several lines, including Lathe, Boring, CNC, and Fitters, and is scheduled for six months during the off-peak season. This strategic project intends to improve personnel skills and efficiency while reducing production disruptions, resulting in greater adaptability during peak demand periods.

The following (table 34). Covers Qadri Group's revised hiring criteria and training needs for different employee classifications. It outlines the abilities, age, literacy requirements, and training durations for three sorts of employees: permanent, contractor, and daily wage. Permanent personnel must be semi-skilled and between the ages of 20 and 45, with a minimal literacy level.

New Hiring Criterion and Training				
	Skills	**Age**	**Literacy**	**Training period**
Permanent	Semiskilled	20-45	Minimum Tech Training Centre	6 months in Off-peak season
Contractor	Semiskilled / Skilled	20-45	Minimum literate	2 months of guided training in Performing assigned tasks.
Daily Wager	Unskilled	20-45	Literate	-

Table 34. Proposed criteria and training for different classifications of employees.

They will receive six months of training at a Tech Training Centre during the off-peak season. Contractors, whether semi-skilled or skilled, are of similar age and must have at least basic literacy skills. They receive two months of guided training for the activities given. Daily wagers are considered unskilled, with a literacy requirement but no set training duration. This organized strategy attempts to improve employee competency and adaptability within the firm.

22 Future to do at Qadri engineering

1. To Organize machine groups in Qadri Engineering based on the operations task carried out on the same machines.
2. Introducing the training pool model and the plan for skill improvement for the upcoming off-peak season to prepare for the 2025 off-peak season.
3. Managing daily wagers and contractual workers along with their skill development.
4. Creating teams in the lathe and boring lines section to reduce the workload and boost worker productivity and efficiency.
5. To study and develop strategies for system improvement by incorporating semi-automated equipment to expand the workforce and enhance labour efficiency.

6. To launch a preventive maintenance Plan, put in place a consistent maintenance initiative for all the equipment to avoid malfunctions during crucial manufacturing periods. By consistently maintaining machinery, the company can reduce the amount of time machines are out of service and guarantee their optimal performance during busy times.
7. The company should support the skills diversity of the employees and encourage the practice of cross-training among staff across different departments to boost adaptability. This will allow the workers to take care of multiple tasks in different sections. Mainly during the peak season when there is a high demand, making the employees more flexible and avoiding relying on specific labour.
8. Create a better work environment for the employees, clean the workplace, and get rid of all the unnecessary waste on the floor to have more space and comfortable work conditions. Improve the ventilation system. Introduce PPEs to avoid risk in the workplace.
9. Implement and respect the use of safety signs to mitigate the risk levels.
10. Purchase and train the personnel on how to use REBA software and conduct the analysis once every month to keep the workflow running efficiently and avoid delays or anything that may slow down production due to the worker's absenteeism.

23 Conclusion

After examining and assessing the work at Qadri Engineering, certain key areas were discovered and solutions were proposed with a planned task for the future in each of the units of the Company. The Qadri engineering workforce is managed with a man-machine ratio of 3:1. The first recommendation is to train employees to run different machines within the same machine groups. Apply Health and Safety principles according to ISO standards. To combat absenteeism, injuries, and talent drainage. The Qadri group should implement an incentive wage scheme to retain permanent personnel while reducing the loss of talented staff.

To solve this problem of talent retention. We propose that Qadri Engineering should implement an incentive-based wage method. This system would not just keep permanent employees but would certainly reduce the number of turnovers among highly skilled employees who tend to leave the company to go and seek greater opportunities somewhere else. By introducing these methods, the company can maximize its labour management while creating a safer and more motivated workplace.

24 Discussion

The primary goal of this thesis was to perform a thorough qualitative and quantitative analysis of workforce management strategies at Qadri Group, particularly during peak and off-peak load periods. The findings reveal significant insights that align with the objectives to be achieved.

Firstly, one of the key deliverables was to determine the optimal staffing levels required during different peak sessions. Through the analysis, it was found that the Qadri Group often experiences challenges related to both overstaffing during off-peak times and understaffing during peak periods. This directly correlates with the intention of improving the company's workforce management strategies, which was evident in the qualitative data collected regarding employee workload and satisfaction. The qualitative analysis identifies the need for a more flexible workforce, which aligns with the thesis hypothesis that flexibility in staffing could lead to improved efficiency and morale among workers.

Furthermore, this thesis aims to evaluate the skills and training levels required for optimal workforce performance. The quantitative analysis provided clear evidence that a well-trained and skilled workforce significantly improves productivity. For example, it was found that during peak periods, those workers with multi-skilling abilities performed better and were less likely to burn out. This finding supports the knowledge base on the importance of comprehensive training programs, as discussed in the literature on human capital theory, which reveals that investing in employee development brings higher returns in productivity.

Moreover, these findings on employee morale and motivation during different demand periods strengthen the understanding of organizational behaviour. It has been discovered that motivation measures, such as recognition and performance incentives, have been proven vital, particularly during peak seasons when workloads increase. This relates to the equity theory, which highlights the importance of perceived fairness in the workplace. Qualitative results showed that when employees felt sufficiently rewarded for their efforts during peak seasons, their overall job satisfaction improved, leading to a stronger workforce.

In brief, the results not only align with the aims mentioned in this thesis but also contribute to the current knowledge base regarding workforce management. The findings' association with existing theories, such as human capital theory and equity theory, approves the research approach and demonstrates the importance of applying theoretical frameworks to practical scenarios in workforce management. This thesis has not only provided insights into the specific challenges faced by Qadri Group but also contributed to the broader conversation on effective workforce management practices in manufacturing industries.

Finally, the findings of this report demonstrate the need for Qadri Group to implement advanced workforce management strategies such as demand forecasting, flexible staffing models, and continuous employee training. These strategies will eventually lead to increased operational efficiency and improved employee happiness and well-being, achieving the goals set out in this thesis.

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Appendix 1

Interview questions on data for the workforce, production, order, current labour strength, organization by section, skill matrix, cost administration and production department.

1. What skills do the current employees possess?
2. How do you rate the efficiency of each worker skill on a scale of 1 to 5?
3. Are there any skills that are lacking in the current workforce?
4. What is the average number of production orders received during peak and off-peak seasons?
5. How does the production output compare to the orders placed?
6. What is the lead time for fulfilling production orders?
7. How many permanent and contract employees are currently employed?
8. What is the distribution of employees across different sections?
9. What is the average time spent by the employees in the organization?
10. What are the average costs associated with labour for both peak and off-peak seasons?
11. How do the operational costs fluctuate based on workforce changes?
12. What budget is allocated for training and skill development?
13. How many workers are assigned to each section in both QadCast and Qadri Engineering?
14. What is the skill level distribution among workers in each section?
15. Are there any cross-training initiatives in place for workers in different sections?

Appendix 2

Manpower Analysis Questionnaire

1. What is the current workforce strength at Qadri Group?
2. How are the skills categorized within the workforce, and what percentage of employees fall into each skill category (highly skilled, skilled, semi-skilled, unskilled)?
3. What are the age demographics of the current workforce?
4. How does the literacy rate among employees impact the overall productivity and efficiency of the workforce?
5. What specific ergonomic assessments were conducted to evaluate the risk factors for workers in the fettling section?
6. What specific training programs are proposed for improving the skills of the workforce?
7. How does the current workforce aim to reduce skill drainage and enhance productivity during peak and off-peak seasons?
8. How does the analysis suggest addressing issues with casting defects and employee absenteeism?
9. What are the financial implications of the proposed changes in the workforce structure, including costs associated with new hires and training programs?
10. How do the current and suggested workforce strengths correlate with the production goals of the Qadri Group?

Appendix 3

Financial Analysis of the workforce interview questions

1. What are the total costs associated with the current workforce structure at Qadcast and Qadri Engineering?
2. How do the manufacturing costs for FLS-19 Hammers and FLS-08 Grate Plates differ based on the current workforce efficiencies?
3. What are the estimated financial impacts of hiring additional workers versus relying on current staff during peak and off-peak seasons?
4. How would the implementation of a training pool model affect overall labour costs and productivity?
5. How is the budget allocated to training and skill development to ensure workforce optimization?
6. What percentage of the overall operating budget should be dedicated to employee incentives during peak seasons?
7. Do you know what lean is and do you know the benefits of implementing lean principles for good optimization?
8. How do the costs associated with employee turnover and absenteeism impact the overall financial health of the Qadri Group?
9. Based on historical data, what are the expected financial outcomes for Qadri Group if current workforce management strategies remain unchanged over the next fiscal year?
10. How does demand forecasting play a role in financial planning for workforce management?
11. What are the average salaries for different skill levels within the workforce, and how do these impact overall labour costs?

12. How do compensation packages influence employee retention and performance during peak periods?
13. What financial risks are associated with overstaffing during off-peak periods, and how have you been trying to mitigate these?
14. How does the variability in demand impact financial stability, and what strategies have you implemented to manage this risk?