Impact of Human Errors on Maintenance Performance in Atbara Flour Mill Factories

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Abstract

The research on Grain Milling Factories Company Ltd. aims to analyze the flour production process, including essential stages like cleaning, grinding, and sieving, while identifying key equipment involved, such as conveyors and grinding machines. It explores the prevalence of human errors in maintenance due to factors like time pressure and inadequate training, which contribute to operational risks and inefficiencies. The study assesses the effectiveness of current human error management programs and notes dissatisfaction among workers, highlighting the need for improvements. Recommendations focus on enhancing training, communication, and management practices to promote safety and operational excellence. Overall, the research underscores the importance of addressing human errors to ensure reliability and safety in flour production, positioning the company as a vital player in Sudan's flour industry since its establishment in 1992.

Keywords: Flour Production; Human Errors; Operational Efficiency; Training Improvements; Grain Milling Industry

1. Introduction

Grain Milling Factories Company Ltd. Atbara, established in 1992, is a key player in Sudan's flour industry and the only factory in the Nile River State. Initially designed to produce 200 tons of high-quality wheat flour per day, the company underwent a significant upgrade in 2003, boosting its capacity to 250 tons per day. This enhancement improved efficiency and allowed for a greater market reach.

To ensure a stable supply chain, the company has invested in robust storage facilities, including silos with a total capacity of 6,000 tons for raw materials. Recently, the factory completed the installation of a new production line capable of processing 300 tons per day, featuring advanced technology for better production control and monitoring.

The company's focus on innovation, efficiency, and quality has established its reputation as a leading entity in the Sudanese flour industry.

Figure 1 below illustrates a 2 Mill Installations from Ugur Group in Sudan taken from Miller Magazine.

Figure 1: A 2 Mill Installations from Ugur Group in Sudan

The objectives of the present research could be summarized as follows: To analyze the intricacies of the flour production process at Grain Milling Factories Company Ltd., including the critical stages of cleaning, grinding, and sieving; to identify the essential equipment involved in the production process, such as conveyors, elevators, cleaning machines, and grinding machines; to investigate the prevalence of human errors in maintenance practices and the contributing factors, such as time pressure and inadequate training, which lead to operational risks and inefficiencies; to assess the effectiveness of current human error management programs, highlighting areas of misunderstanding and dissatisfaction; to recommend improvements in training, communication, and management practices to enhance safety and operational excellence within the milling operations; and to emphasize the significance of addressing human errors to ensure optimal reliability and safety in the flour production process, [1], [2] and [3].

2. Historical background on Flour

Flour, one of the most fundamental foodstuffs in human history, has significantly influenced our lives for thousands of years. Since early times, people have been grinding various cereals to produce flour, using it to make bread, pasta, and pastries. The origins of flour trace back to the dawn of agriculture around 10,000 years ago when humans began planting and harvesting grains like wheat and barley. Initially, stone mills were used to grind these grains into flour, with archaeological evidence indicating that the first stone mills appeared in the Middle East around 6000 BC. Over time, while

the primitive methods evolved, stone mills remained the dominant means of flour production for centuries.
In ancient civilizations such as Egypt, Mesopotamia, and the Roman Empire, flour served as a staple food. In Egypt, the baking industry flourished, with flour playing a crucial role in daily nutrition and religious rituals. Mesopotamia utilized flour not just for bread but also for brewing beer. In Ancient Greece and Rome, flour was essential for making various baked goods, including pasta, while during the Roman Empire, flour was obtained from several grains and classified by quality.
Throughout the Middle Ages, flour remained a widely consumed staple in Europe, with the introduction of water and wind mills significantly enhancing production speed and efficiency. Water mills thrived in river-rich areas, while wind mills were favored in windy locales, facilitating greater accessibility to flour-based products such as bread, cakes, and pastries. The late 18th and early 19th centuries marked the Industrial Revolution, which brought about significant changes in flour production with the invention of steam mills. This technological advancement optimized the milling process, improved flour quality, and expanded its reach to a global audience. The Industrial Revolution also allowed flour to be ground more finely and uniformly, simplifying transportation and storage.
In the modern era, flour production benefits from advanced technologies and modern agricultural practices, enabling mills to produce finely-ground and homogeneous flour. A variety of flours catering to different nutritional needs—such as whole wheat, whole meal, and gluten-free options—are now widely available. The emphasis on health has led to a growing demand for organic and whole grain flours, as modern production techniques help preserve and enhance flour's nutritional value.
Flour's importance extends beyond its status as a foodstuff; it holds substantial cultural and economic significance. In various cultures worldwide, flour is a key ingredient in traditional dishes, such as pita bread in Turkey, pizza in Italy, and baguettes in France. Economically, flour is crucial in agriculture and food sectors, providing employment opportunities and contributing to a thriving market for bakery products globally, especially in developing nations where flour production and trade play vital roles in local economies and contribute significantly to national income through exports.
Looking ahead, the future of flour will heavily rely on sustainable agricultural and food production practices. Factors such as organic farming, the use of genetically modified organisms (GMOs), and alternative cereals will influence flour production. Climate change and environmental concerns may also impact this sector, prompting producers to adopt new strategies to adapt. Advances in technology promise to lead to more environmentally friendly and efficient flour production methods, including innovations that reduce water usage and enhance energy efficiency, as well as improvements in waste management and recycling.
Nutritionally, flour is rich in carbohydrates, proteins, and various essential vitamins and minerals. While refined white flour tends to lose some nutritional value during processing, whole wheat and whole meal flours tend to offer greater health benefits, particularly for digestive health due to their high fiber content. However, flour consumption presents challenges for some individuals, particularly those with gluten intolerance or celiac disease, leading to increased demand for gluten-free flour and products.
In conclusion, flour has been a staple food throughout human history, evolving alongside advances in agriculture, technology, and culture. Modern flour production techniques enable the acquisition of higher quality and more diverse flour options that are vital for nutrition, culture, and the economy. The rich history of flour underscores its enduring significance, ensuring that it will remain a fundamental component of dietary practices and cultural heritage for generations to come, [4], [5], [6], [7] and [8].

3. The Stages of Flour Production

The research article outlines the complex stages involved in the flour production process, emphasizing the importance of quality control and efficiency. It begins with the receipt of raw wheat, which must meet strict quality standards before entering the flour mill. The wheat is then cleaned and humidified to remove impurities and foreign grains using equipment like vibrating sieves and suction fans. An electronic device monitors moisture levels, adjusting water addition to ensure optimal processing.

Following cleaning, the wheat undergoes steeping or tempering for 30 to 36 hours, allowing it to absorb water and break down starches, which facilitates grinding and enhances flour quality. The wheat is then processed through screw and vertical conveyors to the grinding stage.

At the milling stage, moistened wheat is accurately extracted from silos and weighed for quality control. It is initially ground in a milling machine, with the resulting product (dredging) conveyed to sieving systems. This sifting process classifies the milled wheat based on granule size, ensuring that different flour products are directed to appropriate grinding machines for further refinement.

Throughout the production, precise control and management are crucial to maintaining quality and consistency, ultimately leading to high-quality flour suitable for various culinary and industrial applications. The combination of traditional methods and modern technology ensures an efficient production process aligned with industry standards, [9], [10], [11], [12] and [13].

4. The Main Machines of the Grain Mill

The Main Machines of the Grain Mill refer to the essential components that facilitate the processing of grains into various products such as flour, meal, and animal feed. The primary machines of a grain mill include the grain reception system, which involves a series of hoppers and conveyors that receive, store, and transfer grains to the milling area.

Next, there is the cleaning system, which employs air jets, sieves, and magnets to remove impurities like dust, stones, and metal fragments from the grain. The gristing machine, also known as the grain breaker, then cracks the grains into smaller pieces, allowing for the separation of different components during the milling process.

The milling machines themselves, including the roll mill and the hammer mill, play a crucial role in reducing grain particles to varying sizes. The roll mill uses rotating rolls to flatten and break grain particles, while the hammer mill employs high-speed hammers to grind grains into fine powders.

In addition to the milling machines, the grain mill typically includes equipment for sifting and sieving, which separate the milled products into different fractions based on their size and quality. This is often achieved using rotary sifters or air sifters, which utilize air flow to separate larger and smaller particles.

Finally, the storage and packaging system of a grain mill is essential for storing the finished products and distributing them to consumers or other processing facilities. This may involve bagging, bulk storage, or even online packaging, depending on the specific requirements of the products being processed, [14], [15], [16], [17], [18] and [19].

4.1 Conveyors and Elevators: Overview and Importance

Conveyors are essential in grain mills, streamlining material transportation across different production stages. They can be categorized into two main types: horizontal and vertical conveyors, each tailored for specific tasks within the milling process.

4.1.1 Horizontal Conveyors

These conveyors transport materials along a flat or sloped surface, crucial for moving raw materials, finished products, and waste. Key types include:

- **Belt Conveyors:** The most common, using a continuous belt for heavy loads. They are adaptable to environmental needs.
- **Roller Conveyors:** Featuring side-loading capabilities for heavy-duty applications.
- **Chain Conveyors:** Effective for bulk materials like grains, able to function in harsher conditions.

Proper maintenance is vital for smooth operation, and horizontal conveyors enhance overall efficiency in milling workflows.

(a) Chain Conveyors

Located in the ore receiving section, these conveyors efficiently transport materials, with a capacity of 50 tons per hour. At the Atbara Flour Mill, five chain conveyors of varying lengths are employed to optimize material flow and processing productivity. Figure 2 below shows a typical chain conveyor used in Atbara Flour Mill Factories.

Figure 2: A Typical Chain Conveyor used in Atbara Flour Mill Factories

(b) Screw Conveyors

These conveyors play multiple roles, including:

- Pulling products from silos.
- Collecting by-products like flour.
- Feeding milling machines and humidification silos.
- Transporting backfills.

With a capacity of 13 tons per hour each, the eight screw conveyors at Atbara Flour Mill ensure continuous production, especially during peak times. Figure 3 below shows a typical screw conveyor used in Atbara Flour Mill Factories.

Figure 3: A Typical Screw Conveyor used in Atbara Flour Mill Factories

4.1.2 Bucket Elevators

Bucket elevators are crucial for handling wheat during reception and processing. They quickly transport wheat from vehicles to storage, handling up to 50 tons per hour. Their functions also include cleaning and humidifying grain, as well as moving flour to silos, helping maintain quality through efficient handling. The standard capacity for flour transfer is 13 tons per hour.

The various conveyors and elevators in grain milling, including their specific designs and capacities, are vital for maintaining efficient operations and ensuring product quality throughout the milling process. Figure 4 below shows a typical bucket elevator used in Atbara Flour Mill Factories.

Figure 4: A Typical Bucket Elevator used in Atbara Flour Mill Factories

4.2 Cleaning Machines: A Crucial Component in Grain Processing

Cleaning machines are essential in grain processing, particularly for maintaining the quality and purity of wheat. Their effectiveness in removing impurities directly influences the final product's texture, flavor, and nutritional value, ultimately impacting consumer satisfaction. These machines operate using vibrating motors that generate high-frequency vibrations, allowing wheat grains to interact with screens that separate impurities like stones and husks from the clean grain, which is then collected for further processing.

Beyond enhancing grain quality, effective cleaning also protects milling equipment from damage caused by contaminants, reducing maintenance costs and downtime, which contributes to a more efficient production process. Modern cleaning machines feature advanced capabilities, such as adjustable vibration settings and multiple sieving decks that accommodate various grain types and requirements. Moreover, some of these machines now include automated systems with sensors and machine learning algorithms that optimize the cleaning process in real time, minimizing manual intervention.

Overall, cleaning machines are vital for grain processing operations, ensuring high-quality wheat products. As demand for such products rises, the significance of advanced cleaning machines with automation will grow, enabling operations to remain competitive and consistently supply high-quality wheat to consumers. Figure 5 below shows a typical cleaning machine used in Atbara Flour Mill Factories.

Figure 5: A Typical Cleaning Machine used in Atbara Flour Mill Factories

4.3 Grinding Machines: Overview and Components

A typical grinding machine comprises two main rollers that rotate in opposite directions, allowing precise control over the smoothness and quality of the final product. Key components include the main rollers, each with a diameter of 25 cm, a length of 100 cm, and a weight of approximately 400 kg, responsible for the grinding action; a nutrition distributor roller that ensures even nutrient distribution; a motor and drive system that connects the electric motor to the rollers via belts; and a gear system that reduces the speed of the secondary roller for efficiency and protection of the main rollers.

Adjustable openings between the rollers enable operators to customize the grinding process for various products, enhancing the machine's versatility. The operational benefits encompass efficient grinding through adjustable rollers, consistent product quality, and straightforward maintenance attributed to a modular design. Regular maintenance is crucial for optimal performance and longevity, involving checks for wear on belts and gears, cleaning of rollers, and motor inspections. Operators should remain vigilant regarding necessary upgrades or adjustments to meet evolving production demands. An accompanying figure illustrates a typical grinding machine, exemplified by those utilized in Atbara Flour Mill Factories. Figure 6 below shows a typical grinding machine used in Atbara Flour Mill Factories.

Figure 6: A Typical Grinding Machines used in Atbara Flour Mill Factories

4.4 Main Sieves: Design and Functionality

The main sieves in the mill are essential for the sifting process, designed to efficiently separate particles of varying sizes while maintaining continuous operation. These robust components consist of durable nylon cloth stretched across strong frames, with precision-cut holes tailored for specific particle sizes. Central to each sieve is a drive shaft connecting a ball at both ends, allowing for precise control over the sifting action. This drive shaft is linked to a column-mounted eccentric weight, which provides necessary controlled movement, vital for complete particle separation.

With a significant weight of 5.5 tons, the main sieves are built to endure continuous operation, enabling effective particle separation. They are designed for easy unloading, facilitating maintenance and ensuring optimal operational efficiency with minimal downtime. The incorporation of these sieves allows operators to manage material flow efficiently, enhancing processing capabilities and reducing waste. Overall, the precision engineering and durable construction of these sieves are crucial for the mill's success, ensuring a reliable and effective sifting process. Figure 7 below shows a typical sieve used in Atbara Flour Mill Factories.

Figure 7: A Typical Main Sieve used in Atbara Flour Mill Factories

4.5 Semolina Sieve

The semolina sieve is a specialized vibrating sifter that is essential in the milling process for producing semolina flour, which is derived from durum wheat. This sieve is distinct from standard flour sieves, featuring specifically sized openings tailored to achieve the coarse and gritty texture characteristic of semolina flour. Its vibrating mechanism enhances efficiency by enabling the consistent separation of fine semolina particles from coarser fragments, ensuring a uniform product. This is particularly important in sweet production, where the unique texture of semolina flour affects the mouthfeel and structural integrity of various confections like puddings and pasta. By optimizing the sieving process, manufacturers can enhance the quality of semolina flour, leading to superior culinary outcomes. Ultimately, the semolina sieve is a vital component of the milling industry, ensuring high standards of quality and consistency necessary for various culinary applications. Figure 8 below shows a typical semolina sieve used in Atbara Flour Mill Factories.

Figure 8: A Typical Semolina Sieve used in Atbara Flour Mill Factories

4.6 High Pressure Fan

The high-pressure fan is a specialized piece of equipment that plays a crucial role in the milling process, particularly in flour transfer. Operating at high speeds, the fan is able to generate significant negative pressure, which is essential for effectively moving flour from the grinding machines located on the lower levels of the mill to the main sieves situated on the upper levels. In the case of the Atbara Flour Mill Factories, the high-pressure fan is a typical component used to facilitate the efficient transfer of flour between the different floors. Figure 9 below shows a typical high-pressure fan used in Atbara Flour Mill Factories.

Figure 9: A Typical High-Pressure Fan used in Atbara Flour Mill Factories

The high-pressure fan is a vital element in the flour milling process, ensuring efficient and swift transport of flour for further processing and quality control. Powered by a 75-kilowatt motor, it effectively manages air pressure, optimizing material flow within the facility. This contributes to consistent production rates and quality standards. Overall, the fan's design and capacity make it crucial for maintaining operational efficiency, reliably facilitating the transition of flour through various stages of production.

4.7 Low Pressure Fan

The low-pressure fan is an essential auxiliary component that works alongside the high-pressure fan system to enhance air circulation and maintain steady airflow within the system. Its design is integral for optimizing overall ventilation, as illustrated by the typical low-pressure fan used in Atbara Flour Mill Factories, depicted in Figure 10.

Figure 10: A Typical Low-Pressure Fan used in Atbara Flour Mill Factories

Research indicates that in systems requiring substantial airflow, a combination of high and low-pressure fans is often used to achieve optimal performance. The high-pressure fan, engineered to handle substantial resistance and move air at higher pressures, is the primary driver of airflow in such systems. However, its effectiveness can be enhanced by supplementing its airflow with the assistance of a low-pressure fan. Unlike the high-pressure fan, the low-pressure fan is specifically tailored to manage lower pressure environments and is designed to operate quietly and efficiently, reducing energy consumption. Its design enables it to provide necessary airflow without overpowering the high-pressure fan, allowing for balanced air distribution and preventing potential issues related to pressure imbalances. In fact, the low-pressure fan plays a crucial role in maintaining optimal airflow dynamics, improving system responsiveness, and extending the lifespan of both the high-pressure fan and the overall system. By working collaboratively with the high-pressure fan, the low-pressure fan ensures that air is moved effectively throughout the system, enhancing performance and reliability in various operational contexts. Therefore, the low-pressure fan is not merely an auxiliary component but rather an essential component in maintaining optimal system performance and efficiency.

4.8 Flour Filter

In grain processing facilities, the flour filter plays a vital role in maintaining air quality while preventing the loss of valuable flour during the operation of high-pressure fans. When the fans are in operation, they create a strong airflow that disrupts flour particles, lifting them into the air, but the flour filter captures these particles, preventing them from being released into the external environment and reducing pollution. By trapping the flour particles, the filter enhances resource efficiency, thereby decreasing waste generated during the milling process.

In addition to its environmental and economic benefits, the flour filter is also essential for workplace safety. By controlling dust emissions, it reduces the risk of respiratory issues among workers and minimizes the potential for fire hazards, which can arise from the accumulation of fine flour dust in confined spaces. Regular maintenance and timely replacement of filter elements are crucial to maintain optimal performance, and facilities should implement a scheduled inspection routine to ensure the flour filter operates efficiently and maximizes both productivity and environmental compliance.

Modern flour filters are designed to handle varying production capacities, showcasing the versatility and importance of this device in sustainable flour production systems. By utilizing advanced filtration technologies, these filters can effectively capture airborne flour particles, preventing loss and reducing waste, while also ensuring a safe working environment for employees. The flour filter is an essential component in grain processing facilities, highlighting the significance of maintaining a well-functioning flour filter system, as evident in the Atbara Flour Mill Factories where a typical flour filter is used. Figure 11 below shows a typical flour filter used in Atbara Flour Mill Factories.

Figure 11: A Typical Flour Filter used in Atbara Flour Mill Factories

4.9 Compressed Air Machines

Compressed air machines are integral to the efficient functioning of milling operations, particularly for running grinding machines and scales. In our facility, we utilize a comprehensive air compression system comprising three main units to cater to the varying demands of our processes. Two of these units are reciprocating compressors, recognized for their ability to consistently deliver high-pressure air. They achieve this through a series of pistons that compress air in a reciprocating motion, essential for effective grinding and accurate scale measurements. The third unit, a screw compressor, employs two helical screws for air compression, providing a continuous flow that is particularly beneficial for sustained operations while maximizing energy efficiency. Additionally, a rotary piston blower has been installed to operate the flour filter, which is crucial for maintaining product quality by removing impurities from the flour before packaging. Collectively, these compressed air machines form a cohesive system critical for optimal milling performance, enhancing productivity, reliability, and the quality of the final product. This ensures a constant supply of compressed air, allowing precise operation of grinding machines and scales and reflecting our commitment to high standards in milling processes.

4.10 Scales

The mill is equipped with a state-of-the-art system of electronic scales, which are specifically designed to meet precise weight specifications, playing a vital role in ensuring accuracy and efficiency in the milling process. The six individual electronic scales in operation are calibrated to provide reliable measurements, catering to various operational needs, and are used not only for weighing raw materials before processing but also for monitoring the consistency of the output to maintain quality control. These scales feature user-friendly interfaces, can be customized to set specific weight parameters, and are highly adaptable to the mill's diverse operations, allowing for a streamlined workflow and minimizing human error, which ultimately enhances productivity and ensures product quality. Furthermore, the implementation of these electronic scales represents a significant advancement in the mill's operational capabilities, enabling real-time data tracking and reporting, which allows for more informed management of resources and facilitates quick adjustments to processes as needed, marking a notable improvement in the mill's overall efficiency and effectiveness.

4.11 Auxiliary Machines

Auxiliary machines are essential in manufacturing, performing secondary functions that support primary operations on the production line. They work alongside main processing equipment like detachers to enhance task efficiency. A significant role of these machines is to break down cohesive milled atoms created by smoothing machines, ensuring that materials can be effectively sifted and sorted for further processing or packaging. By aiding in the separation and processing of these materials, auxiliary machines promote a continuous and efficient production flow, leading to heightened productivity and improved quality control. Examples of such machines include sorting machines, conveyor systems, and vibrating screens.

4.12 Silos: A Crucial Component of the Mill's Infrastructure

The mill's internal silos play a crucial role in the processing and production of its core products. Constructed with durable steel, these silos are designed to efficiently store and manage various raw materials, particularly ore and hydration ingredients, throughout the production process. Divided into two categories, the eight internal silos have a combined capacity of 720 tons, enabling the mill to handle significant volumes of raw material without interruptions to the production line. Four silos are designated for storing ore before cleaning, providing a continuous supply of quality raw material, while the remaining four silos are dedicated to hydration, storing the necessary ingredients required for creating various flour products. This seamless integration allows the production process to run smoothly.

In addition to the internal silos, the mill features a dedicated flour silo with a capacity of 56 tons, specifically designed to store high-quality flour for distribution to customers. This unique size ensures that only the freshest and highest-quality flour is available at all times, meeting the expectations of discerning customers.

Beyond internal storage, the mill utilizes external silos made of galvanized iron, boasting a total capacity of six thousand tons. These silos provide a secure and controlled storage environment for the mill's products, outside the main processing area. This configuration allows for efficient distribution and supply chain management, ensuring that customers receive their orders in a timely manner. The external silos play a critical role in the supply chain, supporting the mill's ability to respond quickly to customer demands while maintaining a high level of product quality. With their substantial capacity, these silos ensure that the mill can handle fluctuations in demand and supply, guaranteeing that customers continue to receive the high-quality products they have come to expect.

4.13 Power Plant Overview

The Power Plant serves as the main energy source for the mill, equipped with two industrial-grade generators, which together provide a maximum output of 1.2 megawatts. To ensure continuous operation, especially during peak periods, the generators are alternated every six hours, optimizing their cooling and maintenance, thus enhancing their lifespan. The mill, when operating at full capacity, consumes approximately 0.5 megawatts, allowing the Power Plant to meet its energy requirements while maintaining a reserve for any unforeseen fluctuations in energy needs.

5. Results and Discussions

5.1 Section 1: Questions About the Existence of Human Error Programs in Maintenance

The research article presents a series of interview questions aimed at assessing the understanding and management of human error within maintenance programs in organizations. It begins by gauging the respondents' knowledge of human error in maintenance, followed by inquiries about the existence of such management programs in their companies. Respondents are asked to specify the duration of any existing programs and whether there have been any studies or initiatives related to human error management in the absence of a formal program. Finally, the questions seek opinions on the necessity of having a dedicated program for managing human error in maintenance roles. The aim of these questions is to evaluate current practices and highlight the potential need for improved systems to address human error in maintenance activities. Table 1 below presents inquiries regarding the presence of human error programs in maintenance.

Table 1: Questions About the Existence of Human Error Programs in Maintenance

Question No.	Poor	Fair	Better	Excellent	Mean	Std.	Percent	T test	Sample direction	Rank
1	75%	6.3%	6.3%	12.5%	1.56	1.094	33%	5.715	Poor	1
Question No.	**Strongly agree**	**Agree**	**Disagree**	**Strongly disagree**	**Mean**	**Std.**	**Percent**	**T test**	**Sample direction**	**Rank**
2	18.8%	37.5%	18.8%	25%	3.06	1.569	61.2%	7.806	Agree	2
3	0%	12.5%	0%	87.5%	1.38	1.025	27.6%	5.367	Strongly disagree	3
4	0%	0%	6.3%	93.7%	1.06	0.250	21.2%	17.000	Strongly disagree	4
5	100%	0%	0%	0%	5.0	0.000	100%	0.000	Strongly agree	1

Question 1: Indicate Your Level of Knowledge of Human Error in Maintenance?

The analysis of responses regarding the respondents' knowledge of human error in maintenance reveals a significant lack of understanding in this area. A striking 75% of participants rated their knowledge as "Poor," with only a minor representation of ratings at "Fair" (6.3%), "Better" (6.3%), and "Excellent" (12.5%). This overwhelming perception points to a general inadequacy in knowledge about human errors related to maintenance tasks.

Statistically, the mean score of 1.56 aligns closely with the "Poor" rating, and a standard deviation of 1.094 indicates some variability in responses, though the skewness towards "Poor" suggests a consensus on the issue. There is a noted discrepancy regarding a claim that 33% rated their knowledge as "poor," which may require clarification since it contradicts the 75% finding. Furthermore, a T-test value of 5.715 indicates that the perceived knowledge level is statistically significant, solidifying the conclusion that the majority truly feels unprepared in this domain.

The consistent identification of "Poor" as the sample direction indicates that this issue necessitates urgent intervention. Overall, the data underscores a pressing need for improved education and training focused on human error within maintenance practices, as the current knowledge deficits may impede effective maintenance operations. Organizations should prioritize addressing this gap to bolster both employee competence and overall operational safety.

Question 2: Is There a Program for Managing Human Error in Maintenance in Your Company?

The research article analyzed the responses to the question of whether there is a program for managing human error in maintenance within a company. The results showed that, on average, respondents leaned towards agreeing that such a program exists, with a mean score of 3.06. This indicates a moderate level of agreement, and the standard deviation of 1.569 suggests a moderate level of variability in the responses. In terms of percentages, 56.3% of respondents agreed that there is a program in place, while 43.8% disagreed.

Further analysis using a t-test revealed a statistically significant result, with a t-value of 7.806, which suggests that the mean score is significantly different from a neutral score. This provides strong evidence that the respondents' perceptions are not neutral, and instead, lean towards agreement. The sample direction was also found to be "agree", which reinforces the idea that the majority of respondents believe there is a program in place.

The question was also ranked second in importance among the survey questions, indicating that it is a highly rated issue among respondents. Overall, the data suggests that there is a positive perception regarding the existence of a program for managing human error in maintenance within the company. However, the presence of a notable portion of respondents who disagree suggests that there may be areas for further investigation or enhancement within the current framework. As a result, the study concludes that while there is a general sentiment that a program exists, it is also an important area for organizational focus and improvement.

Question 3: If a Program for Managing Human Error in Maintenance in Your Company Exists, How Many Years has it been in Existence?

The analysis of survey responses regarding the existence and effectiveness of a program for managing human error in maintenance reveals significant dissatisfaction among employees. Overwhelmingly, 87.5% of respondents strongly disagree with the program's effectiveness, while only 12.5% express any level of agreement. The mean response score of 1.38 indicates a generally negative sentiment, with a standard deviation of 1.025 suggesting a high level of consensus in this dissatisfaction. Additionally, a t-test value of 5.367 indicates a statistically significant difference from the null hypothesis, reinforcing the strong disagreement among participants. The results imply that the program is viewed as either non-existent, ineffective, or unbeneficial.

To address the negative perceptions and enhance the program, it is recommended that the company investigate the underlying reasons for the feedback, implement improvements, and engage employees to understand their needs. Overall, the findings indicate substantial opportunities for growth in managing human error within the organization.

Question 4: If a Program for Managing Human Error in Maintenance Does Not Exist, Is There Study or Initiative Taken to Manage Human Error in Maintenance That was Conducted in Your Organization?

A survey was conducted to assess the presence of programs for managing human error in maintenance within organizations. The survey consisted of a single question, and the responses were analyzed using various statistical methods to draw conclusions. The question, "If a Program for Managing Human Error in Maintenance Does Not Exist, Is There Study or Initiative Taken to Manage Human Error in Maintenance That was Conducted in Your Organization?", was answered in such a way that revealed strong disagreement among respondents that their organization had no study or initiative in place to manage human error in maintenance. A frequency distribution analysis showed that 0% of respondents strongly agreed, 0% agreed, 6.3% disagreed, and 93.7% strongly disagreed with the statement. The mean response was 1.06, indicating that the respondents strongly disagreed with the statement. With a low standard deviation of 0.250, the responses showed minimal variation across the sample. Furthermore, a T-test, implied to have been conducted to compare the responses across the entire population, likely revealed a significant difference. The results suggest that the majority of respondents were against the idea that there was no study or initiative to manage human error in maintenance within their organization. In fact, 21.2% of respondents chose "Disagree", which might indicate that some respondents were hesitant or had a neutral stance on the matter. Overall, the data implies that the respondents perceive their organization as proactive in addressing human error in maintenance, as they were overwhelmingly against the idea that no efforts were being made to manage this issue.

Question 5: Do You Think There a Need to Have a Program for Managing Human Error in Maintenance?

The research article analyzes responses to a survey question about the necessity of a program specifically designed to manage human error in maintenance. The results show unanimous agreement among respondents, with 100% indicating they "strongly agree" that such a program is needed. The statistical analysis reveals a mean score of 5.0 on a Likert scale, with no variability in responses, as

reflected by a standard deviation of 0.000. A T-Test result of 0.000 further supports the conclusion that there is a significant consensus on this issue.
The conclusion emphasizes the critical need for managing human error in maintenance due to its potential safety and operational implications. The article makes several recommendations, including the development of a dedicated program, further qualitative research to pinpoint specific concerns, and the exploration of implementation strategies drawing from successful practices in other industries. Overall, the findings underscore the importance of addressing human errors to improve safety, efficiency, and reliability in maintenance operations.

5.2 Section 2: Questions About the Effectiveness of Program/s or Tools for Managing Human Error

A section of the research article explores questions related to the effectiveness of programs or tools used to manage human error in a company's maintenance processes. Specifically, it asks three key questions: Firstly, it inquires whether the current human error program implemented by the company has shown any improvement in reducing human error during maintenance activities. Secondly, it questions whether the training and initiatives currently available are sufficient to manage human errors effectively. Lastly, it seeks to identify if there is a need for additional measures to be taken to better manage human errors in the maintenance process. Table 2 presents inquiries regarding the effectiveness of programs or tools designed to manage human error.

Table 2: Questions About the Effectiveness of Programs or Tools for Managing Human Error

Question No.	Strongly agree	Agree	Disagree	Strongly disagree	Mean	Std.	Percent	T test	Sample direction	Rank
1	0%	0%	0%	100%	1.00	0.000	20%	0.000	Strongly disagree	3
2	0%	6.3%	63.8%	50%	1.63	0.806	32.6%	8.602	disagree	2
3	75%	6.3%	0%	18.8%	4.19	1.601	83.8%	10.464	Strongly agree	1

Question 1: Has the Human Error Program Currently Implemented Improved Human Error in the Maintenance of Your Company?

Researchers analyzed the effectiveness of the Human Error Program implemented at a company to reduce human error in maintenance. To answer the question "Has the Human Error Program Currently Implemented Improved Human Error in the Maintenance of Your Company?", they collected data from company respondents. The response distribution showed a clear consensus among the 100% of participants, with all respondents strongly disagreeing (0% strongly agreed or agreed) that the program had improved human error. The mean response of 1.00 also strongly leaned towards "Strongly Disagree", further reinforcing this conclusion. There was no variation in responses, indicated by a Standard Deviation of 0.000. Additionally, a statistical analysis using a T test revealed a significant result, with a T test Value of 0.000. The sample's direction was also strongly negative, further aligning with the response distribution and mean. Overall, the data clearly indicated that the

Human Error Program had not been recognized as beneficial by the company respondents, with all participants expressing strong negative feedback. This suggests that significant reassessment of the program may be necessary to improve human error issues within the company and that this area should be investigated for potential improvements or alternatives.

Question 2: Is the Training and Initiatives Currently Available Sufficient to Manage Human Errors in the Maintenance of Your Company?

The analysis of responses regarding the sufficiency of training and initiatives to manage human errors in maintenance reveals a critical view among employees. A significant majority of participants—over 63%—express dissatisfaction, with half of them strongly disagreeing that current training meets their needs. The average response score is notably low at 1.63 on a Likert scale, indicating a clear sentiment of inadequacy. The standard deviation of 0.806 suggests a consistent feeling of dissatisfaction across the board. Almost a third of respondents explicitly state that the training and initiatives are insufficient, which aligns with the overall trend in the data. The t-test value of 8.602 supports the existence of a statistically significant difference, confirming the prevailing consensus that the current training programs may not be adequate for effective human error management in maintenance tasks. In conclusion, the findings signal an urgent need for the company to reassess and enhance its training initiatives to better address human error in maintenance activities, thereby improving operational safety and efficiency. Recommendations include conducting qualitative analyses through interviews to identify specific training weaknesses, reviewing and updating training content to ensure relevance, establishing feedback mechanisms for continuous improvement, and exploring additional training opportunities to fill identified skill gaps.

Question 3: Is There More That Needs to be Done to Manage Human Errors in the Maintenance of Your Company?

A company sought to understand the perceived need for improvement in managing human errors in maintenance operations. To address this, they conducted an analysis of responses to the question "Is There More That Needs to be Done to Manage Human Errors in the Maintenance of Your Company?" The analysis involved examining response distribution, mean score, standard deviation, and significance testing. A significant majority of respondents (75%) strongly agreed that more needs to be done to manage human errors, with a combined percentage of those who agree (81.3%) further reinforcing the need for improvement. The mean score of 4.19 (on a 5-point scale) indicates a strongly favorable attitude toward taking action against human errors. Although the standard deviation of 1.601 suggests some variability in responses, with 18.8% of respondents strongly disagreeing, the T-test value of 10.464 confirms a very strong statistical significance. This robust confidence in the respondents' collective viewpoint strongly confirms the hypothesis, indicating a consensus that there is a need for enhanced measures to manage human errors in maintenance. Based on this finding, the company could benefit from conducting further assessments or focus groups to identify specific areas where improvements can be made, such as training, procedural guidelines, or technology integration to mitigate human error in maintenance operations. With a rank of 1, this question is a top priority for respondents, highlighting a critical area of focus for the company. Overall, the analysis reveals a pressing need for the company to improve human error management in maintenance operations, emphasizing the importance of addressing this issue as a top priority.

5.3 Section 3: Questions About Common Human Errors in Maintenance of Atbara Flour Mill Factories

Which of the Following Human Errors are Most Common in Atbara Flour Mill Factories?

Time pressure; Inadequate pre-planning (allocation of human resource, tools, spares etc.); Inadequate training, knowledge and skills); Management functions (supervision, strategies, etc.); Poor communication and misinterpretation of manuals, procedures etc.); Environmental conditions (e.g. in poor light during night shift etc.); Interruptions during maintenance; Routine and repetitive, causing lack of paying attention to detail.

In the Atbara Flour Mill factories, several common human errors were identified that could adversely affect operations. Key factors contributing to these errors include time pressure, which can lead to

rushed and potentially unsafe decisions. Additionally, inadequate pre-planning, such as poor allocation of human resources, tools, and spare parts, can result in significant operational delays and errors. The lack of adequate training, knowledge, and skills among employees further compounds these issues, leading to mistakes that could have been avoided with proper preparation.
Management functions, including insufficient supervision and strategic planning, have also been highlighted as contributing factors to human error. Poor communication and misinterpretation of manuals and procedures create additional challenges, making it difficult for employees to follow required protocols accurately. Environmental conditions, such as inadequate lighting during night shifts, can further increase the risk of errors. Interruptions during maintenance activities can distract workers and lead to mistakes, while routine and repetitive tasks may cause a lack of attention to detail, increasing the likelihood of human error in these settings. Table 3 below presents inquiries regarding typical human errors encountered in the maintenance of Atbara Flour Mill factories.

Table 3: Questions About Common Human Errors in Maintenance of Atbara Flour Mill Factories

Question No.	Very likely	Likely	Unlikely	Very unlikely	Mean	Std.	Percent	T test	Sample direction	Rank
1	87.5%	12.5%	0%	0%	4.88	0.342	97.6%	57.090	Very likely	5
2	93.8%	6.3%	0%	0%	4.94	0.250	98.8%	79.000	Very likely	2
3	93.8%	6.3%	0%	0%	4.94	0.250	98.8%	79.000	Very likely	2
4	93.8%	6.3%	0%	0%	4.94	0.250	98.8%	79.000	Very likely	2
5	100%	0%	0%	0%	5.00	0.000	100%	0.000	Very likely	1
6	87.5%	12.5%	0%	0%	4.88	0.342	97.6%	57.090	Very likely	5
7	81.3%	18.8%	0%	0%	4.81	0.403	96.2%	47.753	Very likely	7
8	87.5%	6.3%	6.3%	0%	4.75	0.775	95%	24.529	Very likely	8

The dataset provided analyzes responses regarding the likelihood of common human errors in Atbara Flour Mill Factories, revealing several key insights. The responses are categorized into four groups: "Very likely," "Likely," "Unlikely," and "Very unlikely," with a predominant consensus indicating a high likelihood of human errors, as shown by mean scores ranging from 4.75 to 5.00. Notably, a perfect mean of 5.00 for question 5 highlights unanimous agreement that poor communication and misinterpretation of manuals are critical errors. Low standard deviations indicate consistent responses among participants, with the highest variability occurring in question 8, related to routine tasks.
T-test statistics further clarify the statistical significance of the likelihood of these errors, with agreement percentages nearing 100% for several questions, particularly questions 2 through 5. Ranking the errors by perceived likelihood places poor communication as the top concern, followed

closely by inadequate pre-planning, inadequate training, and management functions, all tied for the second rank.

A detailed analysis of each question shows strong consensus around various issues: time pressure (mean 4.88, rank 5) and environmental conditions (mean 4.88, rank 5) were recognized as significant contributors, while interruptions during maintenance and routine tasks were seen as less consequential.

In conclusion, the findings indicate that respondents perceive human errors as major factors impacting operations at Atbara Flour Mill Factories, with a critical focus needed on poor communication, inadequate pre-planning, and training to enhance operational effectiveness and minimize human error.

5.4 Section 4: Questions About the Impact of Human Errors in Maintenance: Which of the Following are the Impact of Human Errors in Maintenance in Atbara Flour Mill Factories?

Unexpected shutdowns or breakdowns; The cost of rework and stoppage which disrupt production; Reduction in plant reliability/availability or direct damage to the plant; Increase safety risk to maintenance personnel, operators, other employees and public; and Damage to environment.

The section discusses the various impacts of human errors in maintenance at Atbara Flour Mill Factories. Key consequences identified include unexpected shutdowns or breakdowns, which can lead to production disruptions and increased costs due to rework. Additionally, such errors can reduce plant reliability and availability, potentially causing direct damage to the facility. There is also a heightened safety risk for maintenance personnel, operators, other employees, and the public. Furthermore, human errors can result in environmental damage, underscoring the broader implications of maintenance-related mistakes. Table 4 below presents inquiries regarding the effects of human errors in maintenance.

Table 4: Questions About the Impact of Human Errors in Maintenance

Question No.	Very likely	Likely	Unlikely	Very Unlikely	Mean	Std.	Percent	T test	Sample direction	Rank
1	100 %	0%	0%	0%	5.00	0.000	100%	0.000	Very likely	1
2	93.8 %	6.3%	0%	0%	4.94	0.250	98.8%	79.000	Very likely	5
3	100 %	0%	0%	0%	5.00	0.000	100%	0.000	Very likely	1
4	100 %	0%	0%	0%	5.00	0.000	100%	0.000	Very likely	1
5	100 %	0%	0%	0%	5.00	0.000	100%	0.000	Very likely	1

The research article analyzes the impacts of human errors in maintenance at Atbara Flour Mill Factories through various metrics. The study utilized a feedback questionnaire with responses categorized into four options: Very likely, Likely, Unlikely, and Very unlikely. The analysis reveals high mean scores, ranging from 4.94 to 5.00, indicating strong agreement among participants that human errors significantly affect various operational aspects. Most responses exhibited zero variability, suggesting consensus, with one question showing minimal variation.

Moreover, the percentage agreement was exceptionally high, reaching 100% for several impacts, denoting uniformity in concerns among respondents. The t-test results were consistently 0.000, indicating statistically significant agreement that could reject the null hypothesis regarding the impacts.

Specific findings highlighted several critical areas of concern, such as unexpected shutdowns or breakdowns, rated at 100% very likely, implying it's a primary concern. Other significant impacts included costs related to rework (93.8% likelihood) and risks to safety and environmental damage, both rated at 100%.

In conclusion, the data underscores a prevailing belief that human errors in maintenance yield severe consequences, including operational inefficiencies, cost implications, and safety risks. Recommendations include prioritizing enhanced training programs, adopting robust maintenance protocols, conducting regular safety audits, and establishing feedback mechanisms to foster ongoing improvements and safety awareness among personnel.

5.5 Section 5: Questions About Managing Human Error or Improving Current Programs: Do You Think That the Following Needs to be Done to Better Managing Human Errors in Maintenance?

Review of management; Assessment of communication effectiveness; Assessment of training. Development and motivation effectiveness; Assessment of the attitude and/or behavior of maintenance personnel; Maintenance performance review; Work design review (capabilities, repetitive, etc.); and Assessment of incident reporting systems

Section 5 discusses key questions regarding the management of human error in maintenance operations. It suggests that several areas need to be reviewed to enhance the effectiveness of current programs. First, there should be a comprehensive review of management practices to ensure alignment with best practices in error reduction. Second, the effectiveness of communication within the team must be assessed, as clear communication is crucial in mitigating errors. Third, an evaluation of training programs is necessary, focusing on their development and motivational aspects to ensure maintenance personnel are well-equipped.

Additionally, there should be an assessment of the attitudes and behaviors of maintenance staff, as these can significantly impact performance and safety. Regular performance reviews of maintenance activities are also suggested to identify areas for improvement. Moreover, a review of work design is recommended to address factors like capabilities and task repetition that may contribute to errors. Lastly, evaluating incident reporting systems is essential to ensure that errors are properly documented and analyzed for continuous improvement. Overall, these measures are aimed at systematically reducing human error in maintenance practices. Table 5 presented below outlines inquiries regarding the management of human error and the enhancement of existing programs.

Table 5: Questions About Managing Human Error or Improving Current Programs

Question No.	Strongly agree	Agree	Disagree	Strongly disagree	Mean	Std.	Percent	T test	Sample direction	Rank
1	87.5%	6.3%	6.3%	0%	4.75	0.775	95%	24.529	Strongly agree	7
2	100%	0%	0%	0%	5.00	0.000	100%	79.000	Strongly agree	1
3	93.8%	6.3%	0%	0%	4.94	0.250	98.8%	57.090	Strongly agree	2
4	87.5%	12.5%	0%	0%	4.88	0.342	97.6%	47.753	Strongly agree	3
5	81.3%	18.8%	0%	0%	4.81	0.403	96.2%	47.753	Strongly agree	5
6	81.3%	18.8%	0%	0%	4.81	0.403	96.2%	47.753	Strongly agree	5
7	87.5%	12.5%	0%	0%	4.88	0.342	97.6%	57.090	Strongly agree	3

The data from a survey on managing human errors in maintenance reveals a strong consensus among participants regarding the necessity for improvements in this area. A key finding is that all questions received predominantly positive responses, with many participants expressing agreement on the importance of addressing various aspects of error management. The review of management stands out with a perfect "100% Strongly agree" score, showcasing unanimous support for its necessity. Other significant topics include the effectiveness of communication and the attitudes and behaviors of maintenance personnel, which received high agreement rates of nearly 94% and 88%.

Mean scores across the questions varied between 4.75 to 5.00, indicating a strong overall agreement, while the average response exceeded 4.80. The relatively low standard deviations suggest a consensus on the respondents' views, further supported by high statistical significance in the t-tests, affirming the robustness of the responses. The review of management ranks first in importance, followed closely by assessments of personnel and system behaviors.

Based on these findings, several recommendations include prioritizing management review and communication improvements, implementing comprehensive training programs, and regularly monitoring the impacts of these changes. Engaging maintenance personnel in discussions about their attitudes and behaviors, as well as establishing or improving incident reporting systems, are also crucial steps suggested for fostering a culture of safety and continuous improvement.

In conclusion, the survey results highlight a strong belief in the need for strategic enhancements to manage human errors in maintenance effectively. Stakeholders acknowledge the associated risks and are eager to pursue actionable improvements in these critical areas.

6. Conclusion

The research findings indicate a significant awareness and acknowledgment of human error issues within maintenance practices at Atbara Flour Mill Factories. A clear consensus emerged among respondents about the inadequacy of existing human error management programs, with a predominant sentiment highlighting substantial gaps in knowledge, training, and program effectiveness. Despite approximately 56.3% of participants agreeing on the existence of a management program, a striking 87.5% expressed strong dissatisfaction with its effectiveness, indicating a pressing need for reevaluation and improvement.

Respondents unanimously affirmed the necessity of a dedicated program for managing human error in maintenance, emphasizing the critical implications this has for operational safety and efficiency. Key contributing factors to human errors were identified, including inadequate training, poor communication, and time pressure. The impacts of these errors, such as unexpected breakdowns, increased costs, and safety risks, further underline the urgency for enhanced management strategies.

In light of these findings, it is essential for organizations to implement systematic reviews of management practices, training initiatives, and communication effectiveness. Stakeholders should actively engage with maintenance personnel to foster a culture of safety and continuous improvement. The data collectively suggests that addressing human error in maintenance is not only beneficial but necessary for optimizing operational reliability and ensuring the overall well-being of employees and the environment.

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