Assessing the Factors Influencing Productivity in Steel Manufacturing Industries

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Abstract

Low productivity is a persistent challenge in diverse industries, necessitating ongoing efforts to identify and rectify its underlying causes. Factors influencing productivity, such as workplace conditions and management practices, are of paramount importance. This study focuses on the crucial steel industry, which plays a foundational role in the economic development of the United Arab Emirates (UAE), serving as a catalyst for numerous associated businesses. The primary objective is to conduct an in-depth exploration of the factors affecting productivity within the UAE's steel industry. This research aims to comprehensively identify these factors, assess their relative significance, and evaluate their impacts using the Analytic Hierarchy Process (AHP) as a decision-making methodology to provide insights that can empower productivity improvement initiatives and enhance the overall efficiency of the steel manufacturing system. According to the outcomes of the research, visionary management (with a weightage of 24.28%), government policies and regulations (16.75%), and financial stability (12.60%) are important factors for productivity improvement in steel manufacturing industries.

Keywords
Manufacturing Industry, Steel manufacturing, Productivity enhancement, Factors affecting productivity, and AHP methodologies

1. Introduction
The steel industry is a cornerstone of global manufacturing, vital for constructing buildings, electrical appliances, automobiles, and machinery. However, its production process is characterized by intensive energy use and substantial environmental impact. Steel production primarily employs two methods: the blast furnace and the electric arc furnace. The former, accounting for over 70% of steel production, relies on recycled iron ore, coal, and steel. In contrast, the electric arc furnace predominantly uses recycled steel and electricity. This process involves filling the furnace with scrap steel, generating heat through electrodes, and reaching temperatures of 1600°C to melt the scrap. To achieve desired metal properties, ferroalloys are added while oxygen is injected to purify the metal. The growth of China's steel industry, catapulting it from the fifth-largest producer in 1980 to the largest in 1996, has raised environmental concerns, including adverse impacts on coal mining regions, substantial water consumption, and significant greenhouse gas emissions. To mitigate these challenges, the adoption of circular economy principles, involving recycling materials like zinc and slag, holds promise for conserving energy in steel production (He et al. 2020).

In the pursuit of profitability and operational efficiency, productivity stands as a paramount goal for organizations. Within manufacturing industries, various influential factors can significantly influence productivity outcomes. A conducive work environment, as highlighted by Malhan (2019), plays a pivotal role in fostering employee satisfaction while minimizing errors. Environmental aspects within the workplace, such as temperature and lighting, exert substantial influence; suboptimal conditions can hinder concentration and job performance. Organized workstations contribute to reduced stress and enhanced focus among employees. Equally significant is the provision of suitable tools, ensuring employees can work efficiently and effectively. Comprehensive employee training holds vital importance in enhancing their skills and capabilities, ultimately leading to heightened productivity. Effective financial management, particularly the adept control of fixed and working capital, emerges as essential for manufacturing industries to maximize their returns on investments. Furthermore, the timely completion of tasks, as underscored by Chand (2014), assumes critical significance for meeting customer demands and, consequently, boosting productivity through increased order fulfillment.

2. Literature Review

The pursuit of heightened productivity is a ubiquitous goal across diverse organizational domains offering an extensive array of products and services. This literature review encompasses a collection of research endeavors spanning different countries and industries, each employing distinctive tools and methodologies to evaluate, measure, and amplify productivity. Among these sectors, steel manufacturing emerges as a linchpin, underpinning the production of pivotal commodities such as buildings, electrical appliances, automobiles, and machinery. Furthermore, it forms the bedrock for critical infrastructure like bridges, skyscrapers, railroads, and various indispensable appliances.

2.1 Literature review related to the improvement of productivity

Kumar et al. (2017) delved into the potential of total productive maintenance (TPM) to enhance overall equipment performance and reduce machine breakdowns within the steel sector resulting in zero breakdowns, accidents, and losses performing a machine-by-machine breakdown study. His investigation, which entailed a meticulous breakdown analysis of each machine, identified three pieces of equipment with the highest breakdown rates: the stacker, cooling bed, and cold saw-2. Consequently, to attain the TPM objective, the implementation of Corrective Action and Preventive Action (CAPA) measures is imperative, particularly for these specific pieces of equipment.

In a study conducted by Mahmoudzadeh and Abri (2015), the impact of information technology (IT) on the efficiency and productivity of manufacturing industries in Iran was evaluated. Drawing data from 23 diverse Iranian industries, the researchers employed two primary methodologies, DEA and panel data analysis, to assess the effects of IT on productivity. Their findings revealed that while the impact of physical capital was negative, IT capital exerted a positive and significant influence on productivity.

Durdyev et al. (2014) identified 27 factors that affect the productivity and perceived service and divided into five clusters. The results of the statistical analysis showed that the workforce cluster and the work management cluster had a greater impact than the financial management cluster and logistics cluster. The authors provided some recommendations for addressing key factors affecting productivity and perceived service quality in Home Improvement Sector in Turkey.

Kazaz et al. (2016) identified 37 factors and categorized them under four groups such as organizational, economical, physical, and socio-physiological factors and analyzed the dispersion of factors within a group. The authors designed a questionnaire survey and collected the data from the 126 craft workers employed in 4 different construction projects. The applied Relative Importance Index technique for analysis and the results revealed that organizational factors group has the highest weighted mean score and the lowest standard deviation compared to the other.

Soekiman et al (2011) identified 113 factors from the previous literatures and grouped them into 4 groups such as supervision factors, material factors, execution plan factors, and design factors. The main objective of this research study was to get the latest information on the key factors that affect the performance of the project in terms of project completion time and to establish the relationship between the key factors affecting the productivity for improving the labor productivity in Indonesian construction industry.

Liu et al. (2023) examined the impact of indoor environmental quality (IEQ) on workplace productivity. They used partial least squares structural equation modeling to investigate the effects of office comfort and well-being on three dimensions of productivity: contextual performance, task performance, and time management. The results showed that office comfort and well-being had a significant direct impact on contextual performance and an indirect impact on both task performance and time management. The authors also highlighted the importance of including design elements that enhance productivity.

2.2 Literature review related to the Analytic Hierarchy Process (AHP)

Sankaranarayanan et al. (2021) examine the possible risks that might create some errors and accidents, which are critical in the textile industries in India. The Analytic Hierarchy Process (AHP) and (TOPSIS) were implemented to recognize the most significant risk, which reduces the industry's performance. As a result, employees' unwillingness was found as the most critical alternative in the textile industry.
Maggie and Tama (2001) investigated that vendor choice of communication system is an essential issue for telecom companies and that the success or failure of telecom services is directly affected by choosing a vendor. This paper used the Analytical Hierarchy Process (AHP), and as a result, they found that using AHP can minimize the time to select a vendor in a telecommunication system.

2.3 Research Gap

From the above literature reviews, most of the research is about improving productivity or how to improve it in different industries like chemical, steel, iron, and other manufacturing industries. Very little research work is assessing the factors influencing productivity. In this project work, we would like to identify the factors influencing productivity in the steel manufacturing industry and use the Multi-Criteria Decision-Making methodology to assess the factors.

3. Problem Description

The issue of productivity fluctuations is a pervasive concern across all industries, driven by a multitude of variables. In particular, the transformative impact of productivity growth is profoundly significant, especially in advanced economies characterized by sluggish labor force expansion and substantial capital reserves, where such growth often constitutes the primary driver of output expansion. These productivity dynamics can potentially pose substantial challenges to both industries and governmental bodies, necessitating constant vigilance and proactive management. Consequently, the assessment and control of productivity become paramount in safeguarding the industry against diverse external influences. This research endeavors to comprehensively identify and prioritize ten distinct factors that exert influence on productivity within the steel industry, ranging from high to low priority, while also elucidating their associated indicators. The following table provides a detailed description of these influential factors. The factors identified affecting productivity in Steel manufacturing industries are listed below in Table 1, with their descriptions.

The primary objective of this research paper is to comprehensively identify and assess the factors influencing productivity in the steel manufacturing industry, with a specific focus on the United Arab Emirates (UAE). This study aims to leverage expert opinions and a literature review to apply the Analytic Hierarchy Process (AHP) as a multi-criteria decision-making tool. By doing so, it seeks to elucidate the critical role of visionary management as the most significant factor affecting productivity in the UAE's steel industry. Ultimately, this research aspires to provide valuable insights and recommendations that can be instrumental in enhancing the productivity and efficiency of the steel manufacturing sector in the UAE, contributing to its sustainable growth and broader economic development.

Table 1. Description of factors influencing productivity in the Steel industry

Factor	Description
Technology	Technology is crucial in any industry through applying scientific knowledge to practical use that allow the steel manufacturing industries to improve their operations effectively, in turn will increase the performance and productivity.
Plant layout	The arrangement of the production facilities need to be planned efficiently for effective utilization of floor space, to reduce unnecessary movement of workforce, materials, and machines. The efficient plant layout helps to utilize the floor space effectively to minimize the hazards, unnecessary movement, and material handling cost.
Market demand	The market demand is another important factor, which influences the productivity of any organization; the high demand will keep the production working continuously and thus will increase productivity.
Manpower and skill requirement	To increase the productivity of any manufacturing industry, it is important to have sufficient number of manpower and the required skill that fit the job.

Process control	Process control includes effective maintenance, monitoring the real-time performance of the operations to maximize the profit and improving the operational safety that minimizes the risk of accidents.
Energy saving	The steel industry actively manages its energy consumption. Energy saving is critical for the industry's competitiveness and reduces environmental impacts such as greenhouse gas emissions. This illustrates how the energy saving is essential for steel making industry in increasing the productivity.
Financial stability	Building a financial system that functions in good times and bad times in the economy likely would affect Steel's sales, financial results, and cash flows.
Material quality	Quality of the raw materials are significant in the manufacturing process since they have the capabilities to manipulate them to create a product element with the desired shape, dimensions, properties and material features.
Government policies and regulations	The government creates a market system to promote the infrastructure required for enhancing steel production and making the system stable. Still, new set of policies, rules and regulations can directly affect the profitability of the steel industry.
).Visionary Management	The management should be visionary, organize tasks and keep a list of priorities for the entire team, monitor effectively, motivate the employees and provide better working environment for achieving the target and improving the productivity.

4. Methods

The Analytical Hierarchy Process (AHP), a component of the Multi-Criteria Decision-Making Method (MCDM), serves as a general theory of measurement. It facilitates the establishment of ratio scales through discrete and continuous pairwise comparisons, whether based on actual measurements or fundamental scales. This versatile method can convert values such as price, weight, square footage, or subjective opinions like feelings, preferences, or satisfaction into quantifiable numerical relationships. In its general form, AHP presents a nonlinear framework that accommodates deductive and inductive thinking, allowing for the simultaneous consideration of multiple factors with dependencies and feedback. Widely adopted across various organizations and businesses, AHP's simplicity makes it feasible for implementation even in platforms like Excel. Within the context of this research, the AHP methodology is proposed for exploring the interrelationships among factors influencing productivity in the steel manufacturing industry. AHP offers a structured approach to decision-making by assessing criteria and alternative options, with stakeholders conducting pair-wise comparisons to determine the relative importance of criteria. This method provides a robust framework for analyzing complex decisions by combining mathematical and psychological aspects. In our case, after calculating the weights' consistencies and determining their dependability. The highest weightage is assigned to a specific criterion; we will select it as the most influential criterion to increase productivity in the steel industry. At the last step of AHP, decision-makers can determine the best alternative by ranking the alternatives with the results.

This paper aims to quantify the factors affecting productivity in steel industries, identify the significant factors in that field, and give recommendations to improve productivity in the organization. The ten factors identified in the previous chapter are used for analyzing the relationship among the factors. This methodology will help Steel industries to increase productivity by considering the most potent factor.

4.1 Application of the AHP to the case illustration

AHP is one of the best tools used to obtain the best and most important criteria related to any problem or issue that happens during the decision-making process. In this report, the Analytical Hierarchy Process is implemented to find out the most influencing factor that affects productivity in steel manufacturing industries. Steel industries are considered the main source of other manufacturing industries, so it is vital to know which factor will support increasing the productivity of that sector. Below are the steps of conducting the AHP in our case study.

Step 1: Define the Problem and goal

The main goal of this report is to identify and assess the factors that influence productivity in the steel manufacturing industry.

Step 2: Structure a hierarchical framework.
The goal of the AHP is to make it easier for decision-makers to structure an MCDM problem in a criteria hierarchy. The figure portrays a hierarchical model with a two-level decision-making structure. The overall goal of this study is at the highest level, while the ten criteria are at the second level.
Step 3: Conduct a pair-wise comparison matrix.
The pairwise comparisons generate a matrix of the criteria's essential components. We have ten criteria, so we will have ten matrices, where the number of matrices is proportional to the number of criteria. Table 2. shows the pair-wise comparison among all the ten factors.

Step 4: Calculate the Eigen vector and maximum Eigen value for each comparison Matrix.
As previously stated, the foundational scale employed for pairwise comparison commences with the assessment of factors and the judgments of decision-makers, focusing on the importance of each component concerning the corresponding element. Because the AHP approach is subjective, information and aspect priority weights can be obtained from a company decision-maker through an interview or a survey questionnaire. The normalized pair-wise comparison Matrix was obtained by calculating the average of each row to get the criteria weight of each factor.

Normalization involves calculating the sum of each column and dividing each number into the columns by its weight. We will end up with a result of 1 in the sum of each column. Furthermore, the priority weights are computed by averaging the rows.

Step 5: Calculate and check for consistency.
Following the estimation of the criteria weights, each weight is multiplied by the first pairwise matrix in Table 3. and added to each row. Then, divide the criterion weights and the weighted sum value to find the ratio.

After establishing the priority weights for each element and forming a matrix, we evaluate consistency by applying the Consistency Index (CI) and Consistency Ratio (CR) formulas, which incorporate Saaty's Random Index (RI) within the Analytic Hierarchy Process. Table 4. displays the obtained consistency ratio. The pairwise comparison is reasonably consistent under the CR conditions.

Step 6: Create an overall priority.
The pair-wise comparison is reasonably consistent since the consistency ratio is less than 10%. So finally, we can use the criteria weights that we got in Step 4 and use them to create the priority ranking.

Step 7: Select the best alternative.
Once we have a reasonable consistency for each criterion weight, we ensure that they are all within the perfect range. The priority weights of each criterion determine the selection of the most influencing factor. In the factors that influence productivity in the steel industry, the criteria with the highest weight is the most important and influential factor. As shown in Table 2, the visionary management has the highest weightage based on the priority weight.

Table 2. Pair-wise Comparison Matrix

Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Technology	1.000	0.500	0.250	2.000	0.333	2.000	0.500	0.333	0.500	0.200
2. Plant layout	2.000	1.000	0.333	2.000	0.500	2.000	0.333	0.333	0.333	0.250
3. Market demand	4.000	3.000	1.000	4.000	3.000	3.000	0.250	3.000	0.250	0.250
4. Manpower and skill requirement	0.500	0.500	0.250	1.000	0.500	2.000	0.333	0.500	0.333	0.333
5. Process control	3.000	2.000	0.333	2.000	1.000	3.000	0.500	0.500	0.333	0.333
6. Energy saving	0.500	0.500	0.333	0.500	0.333	1.000	0.500	0.500	0.333	0.333
7. Financial stability	2.000	3.000	4.000	3.000	2.000	2.000	1.000	3.000	0.333	0.250
8. Material quality	3.000	3.000	0.333	2.000	2.000	2.000	0.333	1.000	0.333	0.333

9. Government policies and regulations	2.000	3.000	4.000	3.000	3.000	3.000	3.000	3.000	1.000	0.333
10.Visionary management	5.000	4.000	4.000	3.000	3.000	3.000	4.000	3.000	3.000	1.000
Sum	**23.000**	**20.500**	**14.833**	**22.500**	**15.667**	**23.000**	**10.750**	**15.167**	**6.750**	**3.617**

Table 3. Relative weights of the factors/criteria

Criteria	1	2	3	4	5	6	7	8	9	10	Weighted Sum Value	Criteria Weights	
1. Technology	0.0480	0.0269	0.0304	0.0864	0.0252	0.0753	0.0630	0.0280	0.0838	0.0486	0.5154	**0.0480**	
2. Plant layout	0.0959	0.0537	0.0405	0.0864	0.0377	0.0753	0.0420	0.0280	0.0558	0.0607	0.5762	**0.0537**	
3. Market demand	0.1919	0.1612	0.1215	0.1727	0.2264	0.1130	0.0315	0.2524	0.0419	0.0607	1.3732	**0.1215**	
4. Manpower and skill requirement	0.0240	0.0269	0.0304	0.0432	0.0377	0.0753	0.0420	0.0421	0.0558	0.0809	0.4583	**0.0432**	
5. Process control	0.1439	0.1075	0.0405	0.0864	0.0755	0.1130	0.0630	0.0421	0.0558	0.0809	0.8086	**0.0755**	
6. Energy saving	0.0240	0.0269	0.0405	0.0216	0.0252	0.0377	0.0630	0.0421	0.0558	0.0809	0.4176	**0.0377**	
7. Financial stability	0.0959	0.1612	0.4858	0.1295	0.1509	0.0753	0.1260	0.2524	0.0558	0.0607	1.5938	**0.1260**	
8. Material quality	0.1439	0.1612	0.0405	0.0864	0.1509	0.0753	0.0420	0.0841	0.0558	0.0809	0.9212	**0.0841**	
9. Government policies and regulations	0.0959	0.1612	0.4858	0.1295	0.2264	0.1130	0.3781	0.2524	0.1675	0.0809	2.0909	**0.1675**	
10. Visionary Manage ment	0.2399	0.2150	0.4858	0.1295	0.2264	0.1130	0.5041	0.2524	0.5026	0.2428	2.9115	**0.2428**	

Table 4. Consistency ratio for the factors

λ max	11.3254503
CI	0.147272257
CR	**0.098840441**

5. Results

The AHP method results show that after identifying and analyzing the relationship between productivity factors using AHP, we came to the following conclusions about this research study:

To obtain a consistent matrix, we calculated the consistency. The calculated consistency ratio is less than 0.1 (0.0988), as shown in Table 4, based on the state of the consistency in step 6. That is, the pair-wise matrix is reasonably consistent, and the weights are trustworthy. To summarize, the criteria weights are critical for identifying the most significant productivity that has the greatest impact on the steel industry. Based on the expert's opinions and the AHP methodology, the results shown in Table 5, that visionary management is the best alternative among all other factors, where management will increase and boost the industry's productivity. Figure 1 shows a representation of the weights for the data calculated.

On the other hand, government policies and regulations, financial stability, material quality, and market demand have the highest weights among the remaining factors after the management. Hence, the steel industry needs special attention to managing these factors to boost the growth of productivity.

The remaining factors are technology, energy-saving, plant layout, and process control. That determines that these factors do not have much impact on assessing the productivity factors in the steel industry.

Table 5. Criteria weights for the factors affecting productivity in Steel industries.

Rank	Criteria	Criteria Weight	%
1	Visionary Management (VS)	0.242827102	24.28%
2	Government policies and regulation (GPS)	0.16754044	16.75%
3	Financial stability	0.126024293	12.60%
4	Market demand	0.121459163	12.15%
5	Material quality	0.084124357	8.41%
6	Process control	0.07546484	7.55%
7	Plant Layout	0.053746214	5.37%
8	Technology	0.047970771	4.80%
9	Manpower and skill requirement (MSR)	0.043182257	4.32%
10	Energy Saving	0.037660564	3.77%

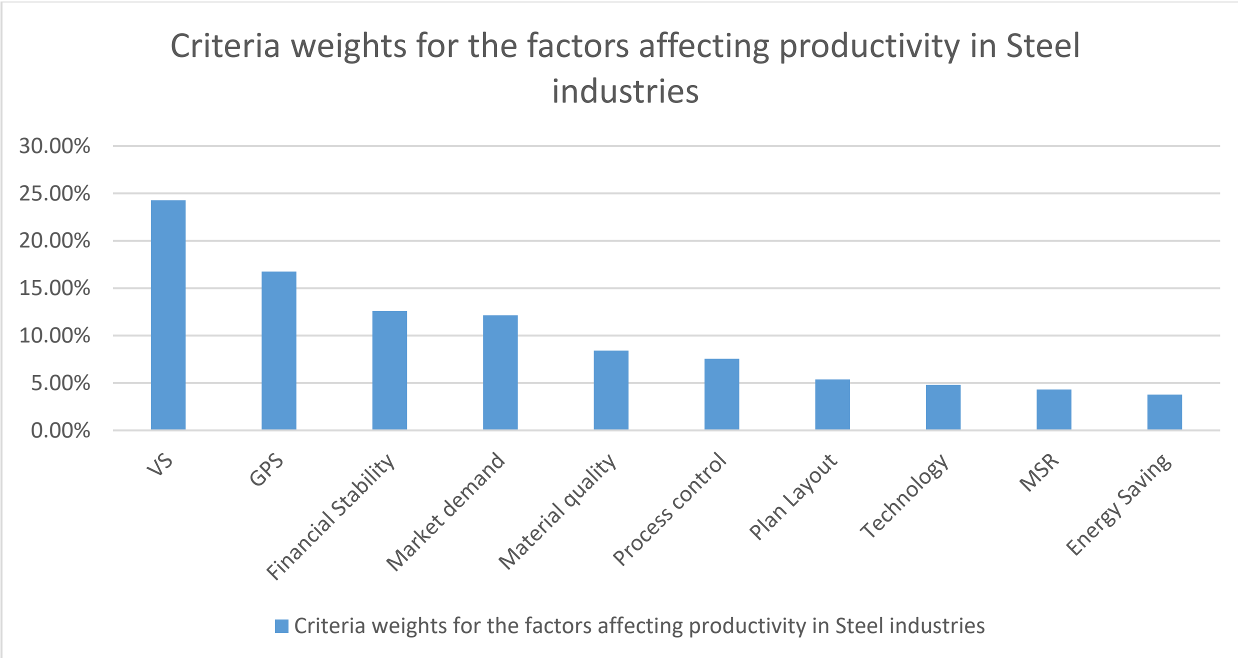

Figure 1. Criteria weights for the factors affecting productivity in Steel industries.

6. Conclusions

In conclusion, productivity is a crucial factor that significantly impacts living standards. Our choice to focus on the steel industry among various sectors was motivated by its role as the cornerstone for numerous everyday objects, including electronics, bridges, machinery, and various devices. This project aimed to identify and analyze the factors influencing productivity in the steel industry, with each factor bearing substantial importance.

To fulfill the project's objective of assessing the determinants of productivity in steel manufacturing, we exclusively utilized the Analytical Hierarchy Process (AHP). Through AHP, we established scales and determined the most favorable alternatives based on expert opinions from Emirate steel companies. The results highlight that visionary management holds the highest criteria weight among all factors, signifying its paramount importance. As indicated in Table 4, factors like energy saving, manpower, skill requirements, and technology were found to have relatively lower impacts on productivity. Conversely, visionary management and government policies and regulations emerged as the most influential factors.

In summary, our analysis using the AHP methodology consistently identifies visionary management as the predominant driver of productivity, followed by the influence of government policies and regulations. Steel industry leaders and policymakers should prioritize these factors to enhance productivity, complemented by the implementation of robust control plans and strategies.

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