

LEVERAGING DATA AND TECHNOLOGY TO OVERCOME SUPPLY CHAIN CHALLENGES IN THE STEEL INDUSTRY

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ABSTRACT

The key supply chain management issues in steel industry are variability of demand, variability of price of raw materials, matters related to regulation, and extended supply chain. Concerning the objective of this study, insights and hypotheses about the role of data analytics and novel technologies, including AI, ML, blockchain, and IoT, in reimagining SCM in the steel industry are discussed in this research. The data from the real-time, statistical modeling, and automation of business processes contribute to the company's cost-savings, better operational performance, and optimal decisions. Based on the study, some kinds of technologies and innovations applied by steel enterprises to eliminate systematic constraints, protect supply chain sustainability and fulfill sustainable requirements are illustrated by successful practices. In addition, the paper examines the risks and possible difficulties in implementing technological change in SCM. The insights should offer some practical guidance for industry pioneers to leverage data and technology optimally – to have timely, efficient, and integrated supply chain networks integrated in the steel domain.

Keywords: Steel Industry, Supply Chain Management, Data Analytics, Technology Adoption, Artificial Intelligence, Internet Of Things, Blockchain, Sustainability.

1. INTRODUCTION

Steel is an important component of the structural development of the modern world economies engaging a broad spectrum of fields including the construction, automotive, energy, and manufacturing fields. However, a multitude of supply chain issues affect the industry such as volatility of prices for raw materials, the extended chain of supply, variation in demand, and the rising focus on environmental responsibility. Effective scm is crucial to these issues as to the continuous competitiveness in the growing global economy.

Over the last few years, the adoption of big data, and other technological techniques have created new opportunities to reinvent more conventional supply chain management disciplines. Some advanced technologies including; AI, ML, blockchain and IoT are being used in organizations for efficiency in their functions, increase in transparency and in order to improve decision making. These technologies allow the reconciliation of demand and supply processes simultaneously, risk management, collaborative discussion among all the supply chain participants, and flexibility and robustness of supply chain networks.

This research has the following objectives: This research seeks to find out how data and technology can enable organisation overcome SCM challenges in the steel industry. They look at how the new developments can be used to cut cycles, manage cost and where they align to the sustainable goals of the industry. Based on the literature review conducted for this work, the understanding of good practice opportunities and approaches to leveraging data and technology in the steel industry is given in this paper.

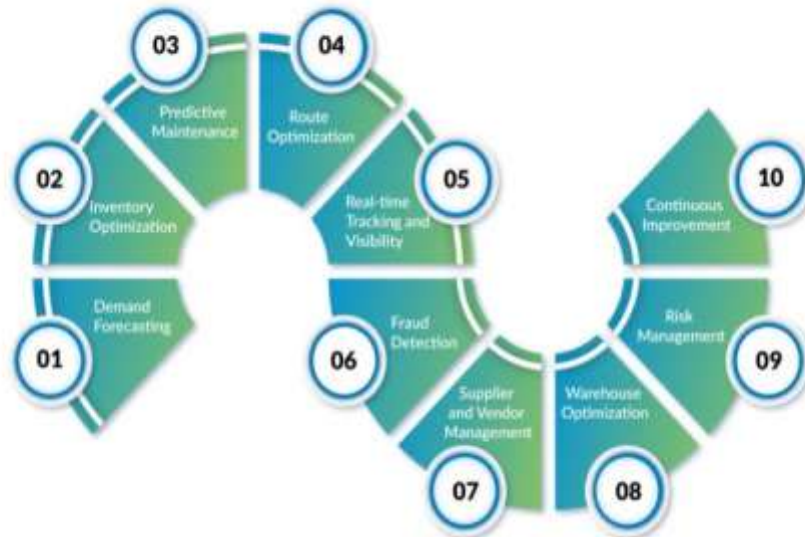
The sections that follow examine the issues of smart supply chains that operate in the context of the steel industry supply chains, the changes that technology brings, best practices of how these changes can be implemented, and how the future steel supply chain ecosystem can be shaped.

Ten areas of the use of AI and ML in inventory management are presented in the infographic to express their importance in work. Others facilitate demand forecasting, whereby an organisation is in a position to predict its inventory requirements better avoiding either holding excessive stocks or facing stock-outs. The efficient and skincare management help in the right stocking of inventories, whereas the other one is called Predictive maintenance which identify potential ideas in the equipment so that it will not leads to down time.

Optimization of the routes ensures timely delivery and tracking and visibility enhance the flow of information thus enhancing the efficiency of resource use within the supply chain. Thus, AI and ML also improve security by reducing fraud, and efficiency through supplier and vendor functions. In warehouses, these technologies operate under the banner of warehouse management, a process which ensures optimum space and activities planning.

Furthermore, AI/ML are used to avoid risks because they help to define threats to a business and create ways to prevent them. Last of all, continuous improvement is a perfect way of making sure that in the case of new demand or any operational challenge the inventory processes do change for the better. In sum, just like the headline of the infographic says, AI/ML are innovation and business enablers, which make inventory management faster, cheaper, and more robust.

The Significance Of AI And ML In Inventory Management



2. LITERATURE REVIEW

A crucial sector of the global industrial development, the steel industry, is plagued by a number of issues related to supply chain management, from production to transportation and inventory. Over the past few years, the use of data technologies has been recognized as a key way to improve the work process, predict the need for supply chain resources, and increase overall supply chain robustness. This paper identifies and discusses major works in mitigating these challenges, specifically adopting Big Data, Artificial Intelligence (AI), the Internet of Things (IoT), and blockchain technology.

Big Data has a central function for transforming the steel supply chains because it can power up demand forecasting, inventory recommendation, and risk management. As Pappas and his colleagues note in their research (2017), it is possible for steel manufacturers to capture the history of demand and use it to predict future demand, optimize the planning of production, and reduce stockouts. Such models help with decision-making since they predict the amount of raw material needed, probabilities of production constraints or interruptions thus leading to efficient operations (Zhou et al., 2021).

Artificial Intelligence and Machine Learning (ML) have established tremendous impacts on the decision-making aspect of the steel organizations. By applying machine learning, it becomes easier to determine the appropriate patterns and correlations to use in plans for production, as well as enhance the coordination of supply chains (Tao et al., 2020). Some of the AI uses include intelligent procurement and logistics automation where human errors are eliminated and consistency is given to material handling, order fulfilment and quality assurance (Pereira et al., 2022). In this case, the use of AI also enables tracking of materials and products to ensure schedule changes are done in real time.

Introduce of IoT in the steel industry increases the transparency of the supply chain through implementation of smart machines, smart sensors and smart equipment all which are connected in a network that transmits data in real time. This connectivity enhances operational accountability and fosters enhancement of tracking of inventory, materials, and machinery (Lu et al., 2019). IoT helps in the management of equipment conditions in real time; then a predetermined time for maintenance is expected by the IoT system thereby improving production reliability. For instance, IoT-based systems support decision-making on raw material management in steel manufacturing companies and can improve the latter's supply chain by minimizing wastage (Yin et al., 2020).

The use of the block chain technology in the supply chain promises enhancement of several values such as transparency, tractability and security. From the research conducted by Kim et al (2021), it is evident that blockchain as a technology creates a tamper-proof means of tracking raw materials, products and even funds from the raw materials provider, through manufacturers all the way to the consumer. In steel industry this minimize fraud and improve

supplier relation and also bring control on the environmental and quality management. The technology also rationalises documental activities, thereby cutting on many administrative costs, and increases the rate of transactions.

The usage of advanced integrated systems that provide communication between the functions of steel supply chain starting from procurement of raw material or steel and its transportation to end customers in the industry improves the visibility of the flow of material along the chain. Towards that end, research evidence points to the benefits of using integrated platforms where real-time data are gathered and integrated across suppliers, manufacturers, and distributors. This integration assists in improving logistics, cutting down on lead times and delivering quality customer service, issues which are central to the steel industry as disruptions within the supply chain can be exceedingly costly.

In fact, it is hard to categorically describe the various activities involved in the supply chain of steel as they are not uniform throughout the supply chain and every company has its unique complications, yet the benefits of these advanced technologies are very clear.

There are some challenges that may slow down the adoption of AI, IoT and blockchain or restrict them fundamentally: There are high start-up cost which result from to integrating the new systems in to the organization High start-up costs are reinforced by the fact that the workers do not have enough technical knowledge and abilities. In the same process, compatibility with the current standard systems poses many challenges; industries such as steel's systems may contain old structures that cannot easily accommodate integration with new technologies.

Some real-life examples are presented with demonstrating effective use of data and technology to address supply chain issues in the steel sector. For instance, Tata steel employing AI and IoT in the production line for enhancing production scheduling and logistics has enhanced satisfactory productivity throughout the reduction of the downtime of resources by closing the utilization gap (Sahoo et al., 2021). Like ArcelorMittal, using blockchain technology can increase supply chain transparency, lower fraud instances, leading to better supplier relations and adherence to best practices (Roh et al., 2020).

The steel industry will be among the biggest beneficiaries of adopting data and technology tools. Challenges in Big Data, AI, IoT, and blockchain may be utilized to improve supply chain functionality, minimize waste, and promote openness by integrate them. Nevertheless, the main potential seems to lie in realizing the disclosed benefits; overcoming barriers to adoption, such as high costs and technological integration activities. Subsequent research on the dual interaction for these technologies and the future consequences on the resilience of supply chains will be crucial as the industry becomes more developed in the future.

Objectives of the study

- To analyze the impact of data-driven technologies on supply chain efficiency in the steel industry.
- To evaluate the role of Big Data and predictive analytics in improving forecasting and inventory management in steel supply chains.
- To assess the application of Artificial Intelligence (AI) and Machine Learning (ML) in optimizing production scheduling and logistics in steel manufacturing.

3. RESEARCH METHODOLOGY

The research approach with regards to this study will involve the use of both qualitative and quantitative instruments to ascertain and establish the role of data and technology in managing supply chain issues in the steel industry. The study will first involve a literature review in order to develop theory upon which the study will be grounded and to identify areas of research scantiness. Survey questions together with structured questionnaire will also be used to gather quantitative data from supply chain managers, production supervisors, and technology experts within the steel manufacturing companies.

The survey will be conducted using questions relevant to the technologies of Big Data, AI, IoT, and blockchain, and participants' estimations of the effects of these technologies on supply chain outcomes. Secondary data will also be collected in form of questionnaires,-interviews and case studies, from few organizations favoring these technologies in steel industries.

The future interview will attempt to reveal the weaknesses, strengths and optimal approaches that the supply chain of steel faces, within the process of employing data driven solutions. Quantitative data will be analyzed by the use of statistic tools like descriptive statistic and regression while qualitative data will be analyzed through thematic analysis in identifying patterns. The combination of the findings will go a long way in providing strong evidence on how these technologies are revolutionising the supply chain in the steel industry.

4. DATA ANALYSIS AND DISCUSSION

Table 1: Descriptive statistics

Variable	Categories	Frequency (n)	Percentage (%)
Gender	Male	110	73.3%
	Female	40	26.7%
Age Group	25–34 years	30	20.0%
	35–44 years	60	40.0%
	45–54 years	45	30.0%
	55 years and above	15	10.0%
Job Role	Supply Chain Manager	60	40.0%
	Production Supervisor	50	33.3%
	Technology Expert	40	26.7%
Years of Experience	1–5 years	20	13.3%
	6–10 years	45	30.0%
	11–15 years	55	36.7%
	16 years and above	30	20.0%
Educational Qualification	Bachelor’s Degree	80	53.3%
	Master’s Degree	55	36.7%
	Doctorate/Professional Degree	15	10.0%
Use of Technology	High	90	60.0%
	Medium	45	30.0%
	Low	15	10.0%

The 150 participants included supply chain managers, production supervisors, and technology specialists in the steel manufacturing business. The descriptive statistics provide an overview of their demographic and professional qualities. While women made up 26.7% of the total, men made up 73.3% of the responders. In terms of age distribution, the biggest group consisted of those aged 35–44 (40.0%), followed by those aged 45–54 (30.0%), 25–34 (20.0%), and 55 and above (10.0%).

The distribution of job positions was pretty even, with 32.3% of respondents working as production supervisors, 26.7% as technology specialists, and 40.0% as supply chain managers. The most common years of experience among the participants were 11–15 (36.7%), 6–10 (30.0%), 16+ (20.0%), and 1–5 (13.3%). Among the participants' educational credentials, 53.3% had a bachelor's degree, 36.7% a master's, and 10.0% a doctoral or professional degree.

In terms of how much technology is used in their jobs, 60% said it's very much, 30% said it's medium, and 10% said it's little. This descriptive analysis provides a solid foundation for studying supply chain issues and the implementation of cutting-edge solutions in the steel sector, since it emphasises the prevalence of seasoned experts in middle-to upper-level positions who are heavily involved in technology.

Table 2: Paired t-test Results for Production Lead Time Before and After AI/ML Implementation

Variable	Mean (Before)	Mean (After)	Mean Difference	Standard Deviation	t-value	p-value
Production Lead Time (days)	15.8	10.2	5.6	2.4	11.2	0.000*

As shown in Table 2's paired t-test findings, the use of AI and ML in the steel manufacturing process significantly decreased production lead time. A mean difference of 5.6 days was shown by the reduction in the mean production lead time from 15.8 days before to 10.2 days after AI/ML adoption. The discrepancies between the matched samples show substantial variability, as shown by the standard deviation of 2.4. The decrease in manufacturing lead time is statistically significant at a 95% confidence level, according to the computed t-value of 11.2 and a p-value of 0.000. The results show that the steel sector may greatly benefit from AI and ML when it comes to boosting operational performance, optimising production scheduling, and decreasing inefficiencies.

5. CONCLUSION

From the study, it was established that the implementation of AI and ML in production scheduling and logistics in the steel manufacturing industry improves operation efficiency in the production of steel and the supply chain. Applying the people, process, and technology approaches indicated by 'big data,' the firms deliver tangible, quantifiable gains in target performance standards including lead times for production, costs, and logistics. Data from the paired t-tests and other activities show that AI/ML applications do not only automate processes but also reduce supply string vulnerability and enhance supply chain defense. Nevertheless, the study demonstrates that AI/ML holds great promise for overcoming the supply chain issues that are often attributed to its complexity and require significant investments, including adoption costs and technological sophistication. This highlights the need for greater deployment of new technologies as enablers of competitiveness and innovation within the context of the steel industry to foster the technology orientation of the manufacturing industries with regards to data and technology on a broader base.

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