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STRATEGIC APPROACHES TO MATERIALS DATA COLLECTION AND INVENTORY MANAGEMENT

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Abstract

For competitiveness provisions in today's intense industrial settings, the collection and management of materials data and inventory are critical for organisational operations and goal attainment. This paper aims to investigate the shift from conventional practices with reference to manual processes to contemporary automated technological tools regards inventory management with regard to barcoding, RFID, IoT, and predictive analysis. It enhances accuracy and real-time information monitoring and consequently would improve decision-making. However, an innovative issue such as data accuracy, integration problems, and large infrastructure costs are some of the barriers that are remaining paramount. The paper also reviews the number of inventory management methods known as Just-In-Time (JIT), Vendor-Managed Inventory (VMI) and ABC classification methods and attempts to discuss how those work in practice. The current trends that are still new to company practices include AI, the use of blockchain technology, robotics as well as cloud computing, as so many practices which can help to bring about changes to the way that inventory is managed. Key themes of the study focus on the impact of the technologies on cost reduction, supply chain dexterity, and efficiency improvement. The study attempts to provide practical insights for enhancing inventory management procedures and gaining a competitive edge in the changing market by evaluating the efficacy of various technologies and tactics.

IndexTerms—Materials Data Collection, Inventory Management, Barcoding, RFID, IoT, Predictive Analytics, Big Data, Machine Learning, Just-In-Time (JIT)

I. INTRODUCTION

In today's highly competitive and rapidly evolving industrial landscape, effective materials data collection and inventory management are crucial for maintaining operational efficiency and achieving strategic goals. Materials data collection entails the collection of accurate and timely

information about raw materials, work in progress, and finished goods to support the decision-making process almost every step of the supply chain. On the other hand, inventory management seeks to optimize the match between supply and demand and ensure that stock is available when need be at an avoidably high cost[1]. These tasks remain important since they reflect on the ability of a business to adapt to changes in the market and satisfy consumers' needs at a lower cost.

The traditional approach to managing inventory has been time-consuming, relying on paperwork and basic inventories; however, technology has changed the landscape of these practices. Techniques such as the use of bar coding systems and Radio Frequency Identification (RFID), assimilated with IoT affiliated devices have improved on real time monitoring and high accuracy of material tracking[2]. In addition, the integration of big data analytics and machine learning has also enabled the enhancement of the predictive attributes on inventory[3][4]. These technological innovations have not only increased productivity but have also offered benefits and strategic advantages to organizations that incorporate them.

The application of complex data gathering approaches in tandem with the contemporary methods of inventory management poses several difficulties. Some issues that organizations face are issues to do with data conformity and adequacy, organizational and technical issues, and having to incur high costs on infrastructures[5][6]. The potential benefits of using this method in hubs have been manifested by experiences from numerous industries despite these barriers. Speaking of Rakuten's LEAP project, one can mention, for instance, inventory optimization. In the US, it was discovered that the implementation of PAA and ML significantly improves forecasting precision and inventory replacement frequencies[7].

Innovation is not only in the technical realm but also in the strategic and operational domains, with their problems to be solved. It is concluded that the materials data collection and inventory management for the effective functioning of an organization is not only about the use of various instruments and technologies but also about designing effective processes and strategies. Data collection systems must fit the organizations' supply chain management systems and more importantly, the organization must have the right skills and ability in data analysis of the collected data[8][9][10]. Also, there is the necessity of flexibility and as a consequence the ability to respond quickly to changes in demand and supply conditions.

This study aims at identifying the key facets of Material Data Collection and Material Management with particular emphasis on supply chain Management and the achievement of organizational objectives. Accurate records are taken and an inventory of data is maintained, which leads to efficient material management and demand and supply balance in an organization thus cutting on the expenditure. These have evolved through technology, bar coding systems, RFID, and IoT have increased efficiency, and accuracy and consist of real-time monitoring. Also, big data analytics and machine learning for predictive analysis help in controlling in advance. However, the problems like data accuracy and its integration are still there. This study seeks to evaluate these innovations and their effectiveness in the enhancement of inventory and operation processes.There are five key contributions for this paper:

- The research demonstrates how manual data gathering methods gave way to automated ones, highlighting innovations like barcoding, RFID, and the IoT that increase inventory monitoring efficiency and accuracy.

- The research shows how predictive skills may improve inventory management, resulting in improved forecasting accuracy and lower operating costs, by examining the application of big data analytics and ML.
- The study offers a comprehensive analysis of various kinds of inventory control strategies including JIT, VMI, ABC classification, and other approaches in organizations and organizations' settings.
- The paper sheds light on main difficulties in data acquisition and catalogue maintenance such as data integrity, integration problems and the necessity of substantial investments in infrastructures, which provide understanding of challenges to organizations.
- Based on the analysis of IoT, AI, blockchain, and robotics, the study identifies the future trends in the field of material data collection and inventory management and underlines the capacity of these trends to enhance the efficiency of organisational processes and organisational competitiveness.

A. Structure of the paper

The following is the outline for the remainder of this paper: Section II offers an overview of Materials Data Collection and Inventory Management, outlining key principles and methodologies. Section III discusses various data collection methods, including manual entry and advanced technologies like barcoding, RFID, and IoT devices. Section IV focuses on inventory management techniques, such as ABC classification, JIT, bulk purchasing, and Vendor-Managed Inventory (VMI). Section V explores future trends, including IoT, AI, blockchain, robotics, and cloud computing. Section VI presents a literature review, summarising previous research and identifying gaps. Section VII offers conclusions and recommendations, while Section VIII outlines future research directions.

II. MATERIALS OF DATA COLLECTION

Materials data collection is one of the strategic activities that form the basis of supply chain and inventory control since it assists managers in decision-making. The techniques of data collection are ever-changing due to technological revolutions that incorporate automation, digitalisation, and big data analytics. The following is a brief presentation of the most common approaches to data acquisition, new technologies, and some of the difficulties related to data quality and compatibility.

A. Data Collection Methods

1). Manual Data Entry

Manual data entry is a process of keying data or writing it by hand, or encoding data into a computer or other data processing systems. This method requires a lot of paperwork and is easily manipulable compared to the technological techniques that are advanced and more effective.

2). Automated Data Collection Systems

Data may be automatically collected and processed with the use of automated systems that use technology. Many people use barcoding, RFID, and IoT devices. Data collecting methods are made more accurate and efficient using these solutions[11].

B. Logistics & Supply Chain

1). RFID Technology

RFID technology employs a field of electromagnetic radiation to detect and follow tags placed on items. It enhances the accuracy and speed of data collection and is widely used in inventory management[12].

2). Internet of Things (IoT)

IoT can be explained as the integration of different devices that communicate as collecting and sharing information. In inventory management, IoT devices can help the managers by collecting data on the amount, location and condition of stocks.

3). Blockchain for Data Integrity

Blockchain technology always ensures that the data contained in the network is accurate through its safe and efficient attributes of recording transactions. As this paper explains, there are various ways that blockchain can be used in the field of SCM such as tracing of commodities and data authenticity.

C. Challenges in Data Collection

1). Data Accuracy

Evaluating the correctness of the data collected is tough, irrespective of the approaches used, provided they are non-automated. There are mistakes during entering the data so get a wrong information for managing inventory [13].

2). Data Integration

That is the process of combining data from different sources into a single set of data known as data integration. It can be cumbersome especially when working with old generation systems or when the formats are different. The integration is a critical process of ensuring that information is complete and the inventory is viewed from two different perspectives to enhance decision making [7].

III. OVERVIEW OF INVENTORY MANAGEMENT

Inventory management which is under the heading of business administration aims to ensure that certain products or objects in stock are at adequate amounts with proper scheduling and monitoring of stock numbers [14]. Finding the sweet spot between overstocking and understocking is the holy grail of inventory management. Because it has such a direct bearing on operational efficiency, customer happiness, and financial goals, effective inventory management is critical. A difficulty of inventory management grows in direct proportion to the number of links in a supply chain. A management of inventory in a multi-tiered supply chain is much more difficult than in a single-tiered arrangement [15].

A. Objectives of inventory management

Businesses, particularly those in the industrial and manufacturing industries, often allocate a significant portion of their financial resources on inventories. On occasion, this budget overrides what is put aside for other assets in the company. Therefore, inventory management becomes an integral part of SCM. To reiterate, the primary goal of inventory management is to prevent both overstocking and understocking while maintaining a steady flow of supplies to meet production needs during peak consumer demand.

1). Cost efficiency

The expenses of inventory management have an effect on the value of inventory via direct means [16].

- **Carrying costs**

Carrying costs are one of the most significant inventory management concerns. These expenses result from the items being kept at distribution centres, retail locations, or warehouses. They include costs for labour, storage, handling, shipping, insurance, taxes, and depreciation. Carrying costs are essentially the entire amount of money spent on stocking and storing goods before they are sold.

- **Ordering costs**

Ordering costs are the expenses incurred while making an order for fresh commodities. This covers the cost of shipping, transportation, inspections, and other order-related expenses.

- **Stockout costs**

Stockout costs are the direct and indirect expenditures a firm bear when its inventory is low. It is important to acknowledge the significant influence that these expenses have on a business's profit margins, sales, and total profitability.

B. Optimal inventory levels

An essential problem for most companies is maintaining an appropriate level of inventory on hand. To achieve ideal stock levels, you need to make sure that amounts are always accessible to fulfil the demand from customers, which means aligning with their real needs. In the same

breath, there are a number of unsavoury outcomes that might affect cash flow and profit margins when stock levels are kept at an excessive level.

1). Demand forecasting

Predicting future inventory requirements, or demand forecasting, is another significant obstacle to effective inventory management. Forecasting the demand at every stage of a supply chain is only a beginning of what supply chain forecasting entails. It entails intricate matters like members exchanging information about end-user demand and coordinating the supply chain.

2). Lead time management

The duration between an order's placement and its subsequent delivery is known as the lead time. During the lead period, it is an essential component of demand calculations (sometimes called safety stock) [17]. The time it takes to complete an order is known as the lead time. The decision-making process when buying items may be influenced by lead time. When lead times are high, businesses become nervous and purchase too much, which leads to excess inventory.

IV. INVENTORY MANAGEMENT TECHNIQUES

A popular IMT that major originations use to efficiently manage a huge number of inventory items is the ABC (Always Better Control). To handle things efficiently, the approach divides the inventory into three categories: A, B, and Q, depending on their relative worth.

A. ABC inventory classification technique

Large companies often use the ABC inventory categorisation approach to effectively handle a substantial amount of inventory items. The ABC Analysis diagram is shown in Figure 1.

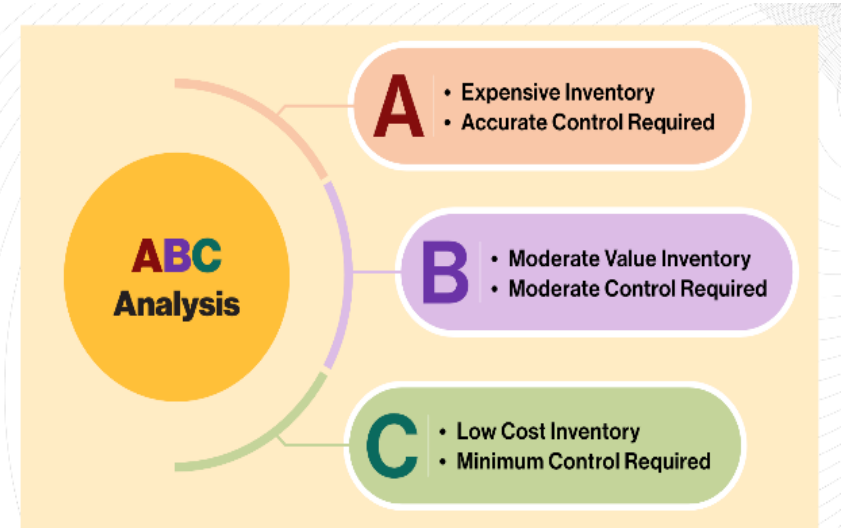

Fig. 1. ABC Analysis

Figure 1 illustrates the technique by which inventories are divided into three main groups: A, B, and C. Things that are categorised as "A" are the most important, whereas goods categorised as "C" are considered to be less important. things are categorised according to a hierarchy: "Class A" things are the most important, followed by "Class B" items and, lastly, "Class C" objects, which are the least important [18].

B. Just-In-Time (JIT) Inventory Management Technique.

The JIT concept aims to replenish an organisation's inventory only when needed. It will be the favoured approach for very costly inventory products, meaning those with low levels of demand but relatively significant purchase prices, hold costs, or ordering costs. The model makes an effort to prevent excess inventory and related expenses. Thus, companies only take on inventory when their demand for more stock is almost at capacity. Making ensuring the vendor delivers on time is essential for the JIT technique to work as planned. The goal of this is to avoid expensive and permanent business interruptions brought on by delays in inventory delivery, which are a significant issue for the operational management of many manufacturers.

1). Bulk-Purchasing.

This approach, which is well-established, is based on the idea that, if you purchase goods in large quantities, the cost of acquisition will be much cheaper. The process must be followed if management is certain that the item in issue is a quick assembly of stock. Consider using this stock management method if a material becomes popular, since it may result in important reserve cash[19].

2). Vendor-Managed Inventory (VMI)

In large-scale measured creation for executives, simple cooperation with reliable basic inventory providers may yield substantial benefits under the VMI strategy. In a seller/client relationship, VMI gives the merchant the ability to plan, screen, and manage stock for their customers. The seller gains control over the stock by managing it within newly established, clear levels, while the client concentrates on advancing interest accuracy [20].

3). Out-Sourcing Inventory Control Personnel

A small number of businesses outsource the creation and administration of their internal stock systems to experts in the field. Accuracy, cycle counting, transportation/receiving, and request selection are all responsibilities of these stock administration experts. Committed stock professionals may work together to deal with all stock items that are nearby and on the way.

4). Out-Sourcing Inventory Control Personnel

A few companies manage and create internal stock systems with the help of outside stock specialists. These stock management specialists are in charge of cycle counting, delivering and

receiving, preserving correctness, and overseeing the request selection process. Committed stock professionals may work together to deal with any stock items that are nearby or on the way.

5). Lead-Time Analysis

Determining how long it takes to refresh your stock by laying up lead-time reports is another really accommodating method of stock management. How long it takes to restock goods is known as the lead time. Upon setting a request, providers send out things at varying times.

6). Software Applications and Tracking System

For companies trying to update their stock control system, putting stock management software into practice has become essential. While there may be many different apps for this kind of thing nowadays, a significant amount of stock management software gives organisations a structured way to depict all upcoming and ongoing stock movements inside their businesses[21].

V. FUTURE TRENDS IN MATERIALS DATA COLLECTION AND INVENTORY MANAGEMENT

The following area provide the future trends in materials data collection and inventory management:

A. Integration of Internet of Things (IoT)

The IoT is transforming materials data collection and inventory management by providing real-time data through smart sensors and devices. These IoT devices monitor inventory levels, track materials, and predict stock shortages, leading to more accurate forecasting and reduced inventory costs.

B. Artificial Intelligence and Machine Learning

A growing number of applications are using artificial intelligence (AI) and ML algorithms to analyse large volumes of data in order to improve SCM, forecast demand, and optimise inventory level [8]. Predictive analytics helps in identifying trends and potential disruptions before they occur, improving overall efficiency.

C. Blockchain Technology

Blockchain enables transparency and traceability in the supply chain since all the transactions and inventories are recorded securely. They are useful in maintaining the general integrity, authenticity as well as minimizing fraud of the inventory management system.

D. Advanced Analytics and Big Data

Big data management helps businesses make informed decisions on various aspects of materials and inventory management. Analytics enhances the quality of business forecasts, reduces complexity and messes in business processes, and enhances decision making.

E. Robotics and Automation

Technology trends such as robotics and automation are today widely used for managing stock. Robotic management of the production line for instance sorting, packing, and counting of stock eliminates human intervention hence enhancing productivity.

- **Augmented Reality (AR) and Virtual Reality (VR):**AR and VR technologies can provide creative methods of visualizing inventory while using a different approach to the standard organization. AR can give information about the inventory items in real time while VR can give information about the layout and organization of the warehouse.
- **Cloud Computing:**Current cloud systems for material data and inventory enable flexibility and scalability in the business. Such solutions make data instantly available, enable teamwork and interconnection with other systems which makes them more effective and prompter.

VI. LITERATURE REVIEW

The existing studies in this field are generally an attempt to use statistical methods to overcome the existing issues associated with materials data acquisition and tracking and outlining possible areas of further research. Recent advancements have integrated machine learning models to enhance predictive accuracy and real-time decision-making. Future research could further explore the integration of IoT devices for more granular data collection and automation in inventory systems.

In this study, Arunprakash N and Nandhini N, (2013) researched several building firms' material control procedures. The writers of this piece developed and evaluated a set of criteria. Various factors are taken into consideration, such as the following: the kind of material stock, the quantity of equipment spare parts, the quantity of materials (including sand, brick, aggregate, steel rod, primer, and cement), the documentation kept, the frequency of stock reorders, and the management of stock. The authors discovered that 50–60% of businesses only paid attention to essential commodities like steel and cement. Since the remaining supplies took up a lot of space and were less crucial to the businesses, their availability on site declined[22].

Madhavarao, Mahindra and Asadi, (2018), this study argues that material management is crucial to the construction industry. Inadequate material identification and project planning lead to increased project expenses and a longer project duration. Lack of materials and improper storage can have a negative impact on labour productivity. Using these techniques, we found a productive way to lower project expenses. Using the S-curve technique, the difference between predicted and actual expenses is analysed. The amount of materials purchased for the project may be ascertained using AB-C analysis[23].

Sahari, Tinggi and Kadri, (2012), examined how inventory management affected the capital intensity and project performance of a Malaysian construction company. The following three indicators served as the foundation for this investigation. 1) ROA as a measure of financial performance; 2) Inventory management is measured by inventory days held (ID); and 3) Fixed assets are divided by the total quantity of inventories and fixed assets to determine capital intensity (CI). The financial data from 2006 to 2010 for 82 organisations was used in this analysis. This study using regression methods to show that inventory management had no impact on performance. Research demonstrated a robust positive correlation between financial performance and inventory management, as well as capital intensity[24].

Zeb et al., (2017)., collected information from stock records and physical stock verification during a number of field trips for a bridge project. The ABC analysis was then completed using MS Excel by following these procedures. (1) Compile item information together with unit costs. (2) Multiply the projected number of units needed by the unit price to get the item's overall worth in the project. (3) Sort the items according to their values in decreasing order. (4) After that, the data were categorised using the ABC system: A represents the greatest value, B represents a moderate value, and C represents the lowest value. S curve analysis of cement was conducted for the detailed study, whereby the projected and actual costs of material procurement were compared. As to the research, stones belong to Class C, aggregates to Class B, and cement and steel to Class A[25].

Madhavi, Mathew and Sasidharan, (2013), included a comprehensive case study, questionnaires, and interviews with experts in the subject. The two main problems with material acquisition are unmet quality standards and project timeline delays. After doing some research, they went on to use a number of inventory management strategies at different businesses, including the FIFO Method and ABC analysis. They also said that the contractor's rate quote prices were lowered by 20% at the job site by using the FIFO Method, which also aided in the timely release of funding and budget process preparation[26].

Aydin Keskin and Ozkan, (2013), demonstrates the use of FCM clustering to uncover a multiple parameter ABC analysis. Stock keeping units (SKUs) are ranked in decreasing order of annual dollar consumption using the old method, which takes the product of unit price and annual demand. To help managers to improve their decision-making processes in uncertain conditions, they applied FCM clustering to a multiple criteria ABC analysis problem in this work. The discovery of the technique which is FCM technique disclose that the method is easy to operate and flexible to use for inventory management[27].

Jebisha and Judit, (2020), analyzed the general protocols such as the software SPSS, EOQ, ABC characterization, and material control in building construction. The authors also did a literature study and analyze data collected from residential projects. investigated and found that the problems of inadequate communication and negligence from the management led to letting wrong and frequent changes of materials on the building site. The project's completion is eventually delayed as a result of all of these factors driving increasing project expenses as well as those associated with keeping or storing inventory supplies[28].

The Table 1 provide the summary of related work with methodology, dataset and limitations & future work

TABLE I. SUMMARY OF RELATED WORK

Ref	Methodology	Dataset	Limitations & future work
[22]	Designed questionnaire, identified companies, reviewed company stock books.	Various construction companies	Limited to selected companies; suggested expanding to more diverse industries and geographies.
[23]	S-curve analysis, AB-C analysis.	Construction project data	Limited to certain materials; future work could explore more materials and different project types.
[24]	Regression analysis on financial data.	82 organisations' financial data (2006-2010)	Limited to Malaysian firms; future studies could include a broader geographical scope and more recent data.
[25]	Field visits, inventory book data, physical stock verification, ABC analysis, S-curve analysis.	Bridge project data	Limited to a specific project type, future work should include various types of construction projects and comparison with other inventory methods.
[26]	Case study, surveys, interviews, ABC analysis, FIFO method.	Construction project data	Limited to selected projects; future research could explore additional inventory control methods and their applications.
[27]	Fuzzy, c-means (FCM) clustering, multi-criteria ABC analysis.	Various stock keeping units (SKUs)	Limited by the complexity of FCM implementation; future work could simplify the methodology and apply it to different contexts.
[28]	Data analysis from residential project, literature review, ABC classification, EOQ analysis.	Residential project data	Limited by inefficient supervision and poor communication; future studies could focus on improving team coordination and communication.

A. Research gaps

The different approaches and their effects on project performance, all underscore the vital role that material management and inventory control play in the construction sector. In order to prevent delays and cost overruns, one research emphasises the need of proper project planning and material identification systems. Although its direct effect on performance was shown to be negligible, another shows the strong link between inventory management and financial performance. A separate study that makes use of field visits and ABC categorisation

demonstrates useful applications in cost management, and a second analysis highlights the effectiveness of FIFO and ABC approaches in lowering material costs and enhancing financial control. Furthermore, a complex method for inventory management under uncertain circumstances is presented using a unique fuzzy c-means clustering methodology for multi-criteria ABC analysis. The analysis concludes by pointing out inefficiencies in the status quo and emphasizing the need for improved communication and oversight. Altogether these works identify the numerous factors and practices of material management and advanced computational technologies and efficient organizational methods and practices to enhance the production and reduce the costs of construction.

VII. CONCLUSION AND FUTURE WORK

This research work offers insight into the process of evolution from conventional handle tools method onto the adoption of integrated technology in materials data acquisition and storing. Pioneering innovations in the kind of barcoding, RFID, IoT, as well as predictive analytics considerably enhanced accurate nuance and real-time tracking. Big data analysis and machine learning integration have brought probable approaches which make forecasting easier and at the same time, decrease operational expenses. However, substantial challenges such as data accuracy issues, system integration issue, and cost of infrastructure investment extend still. Since JIT, VMI and ABC classification strategies have been implemented in organizations, this research has looked at how they helped where they have been adopted. Some of the trends that are already apparent include AI, blockchain technology, robotics and cloud computing, all of which will help to revolutionize inventory management even more. The study focuses on the two principles of enterprise success where integrated applications of technologies and sound procedures are used to enhance inventory control and general performance.

The following areas, should, therefore, be the aim of future research to enhance the collection of material data and inventory systems: First, integration and data sharing across multiple data sources and systems; and compatibility of legacy systems with contemporary higher education technologies would significantly increase the accuracy of the data collected and the value of the decisions expected from these data. Second, there is a possibility to improve demand forecasting and to optimize inventory management by extending the knowledge of advanced methods of predictive analytics and machine learning – for example, through the work with ensemble methods and deep learning.Third, examining the potential of IoT devices for granular data collection and real-time monitoring, along with standardized data exchange protocols, will be crucial. Additionally, assessing the implementation of blockchain technology for transparency and traceability in supply chains should be prioritized. Future work should also evaluate the impact of robotics and automation on warehouse operations and explore the implications of emerging technologies like Augmented Reality (AR), Virtual Reality (VR), and cloud computing on inventory management practices. Addressing these areas will help optimize supply chain efficiency and support organizations in achieving their strategic objectives.

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