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A REVIEW OF SPARE PARTS INVENTORY MANAGEMENT: DIFFERENT METHODS OF SPARE PARTS CLASSIFICATION AND INVENTORY CONTROL TECHNIQUES

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Abstract

The research is a review that covers various methods and techniques for spare parts management. It discusses traditional and modern forecasting methods, as well as different approaches to inventory classification and multi-criteria analysis. The paper identifies scientific gaps in the field of spare parts management and proposes new features to improve prediction accuracy. The study also highlights the importance of effective spare parts management in optimizing storage costs and ensuring the availability of raw materials and products. It addresses the challenge of disruptions in the production flow, which is a critical concern for companies, particularly those involved in manufacturing automobile engines. The research proposes a hybrid approach that combines both qualitative and quantitative methods, incorporating Vital–Essential–and Desirable (VED) analysis, and other techniques of spare parts classification methods. The goal is to identify and prioritize spare parts to be stocked efficiently. The aim of the study is to create a good classification that includes all possible criteria to ensure a good classification of spare parts, previous studies based their classification on one, two or three criteria at most, and this is not sufficient to calculate Re-order Point (ROP) and Economic Order Quantity (EOQ) with high accuracy based on changes in the market and supply chains.

Keywords: Spare Parts Management, Spare Parts Classification, ABC Analysis, VED Analysis.

1. INTRODUCTION

In keeping any operation running smoothly, spare parts management plays a crucial role. It's a delicate balance between ensuring your necessary parts are readily available to avoid costly downtime and reducing inventory costs by not holding unnecessary inventory. This is where the science and art of spare parts management come into play. Each method and technique act as a tool, contributing to the harmonious flow of process. Historical data, industry trends, and even predictive analytics are used to forecast future demand for each spare part. These methods deal with optimizing inventory levels, using techniques such as ABC classification to prioritize important parts and Economic Order Quantity (EOQ) to balance ordering and holding costs.

But portion management isn't just about numbers; It's also about location and accessibility. Enter into stocking and storage strategies, and act like stagehands to ensure that every instrument is readily available to the musicians. These strategies focus on improving warehouse layout, implementing barcode systems, and even exploring

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automated warehousing solutions. Here, technologies like preventative maintenance and vendor management work together to ensure timely repairs and optimal supplier relationships, keeping the music playing without interruption.

This is just a quick overview of the various methodologies in spare parts management. The ideal approach is a careful combination of these techniques, tailored to the specific needs of your operation. So, let this introduction be your starting point, the research paper is a comprehensive review of various methods and techniques for spare parts management. The paper covers both traditional and modern forecasting methods, including deep learning neural networks, as well as different approaches to inventory classification and multi-criteria analysis. One of the key takeaways from the paper is the importance of reviewing old literature in the field of spare parts management. By examining previous research, we can identify scientific gaps and build on existing knowledge to develop new and more effective methods for spare parts management.

The paper also emphasizes the importance of effective spare parts management in optimizing storage costs and ensuring the availability of raw materials and products. This is particularly important for companies involved in manufacturing automobile engines, where disruptions in the production flow can have significant consequences. To address these challenges, the paper proposes a hybrid approach that combines both qualitative and quantitative methods, incorporating Vital–Essential–and Desirable (VED) analysis, analytical hierarchical process (AHP), and e-constraint optimization methods. The goal is to identify and prioritize spare parts to be stocked efficiently. The research aims to provide insights and actionable recommendations for effective spare parts management in different contexts, taking-into account the specific needs and challenges of each industry. By reviewing old literature and building on existing knowledge, we can develop more effective methods for spare parts management and ensure the smooth operation of production processes.

2. METHODOLOGY

Classifications of Spare Parts

- **ABC Analysis:**
  - A widely used method for classifying spare parts based on annual consumption value [1, 3, 4, 5, 6].
  - Classifies parts into A (high value), B (medium value), and C (low value) categories [1].
  - Helps prioritize inventory control efforts and resource allocation [3, 4, 6].
- **VED Analysis:**
  - Considers the Vulnerability, Effect on System, and Difficulty to replace of spare parts [10].
  - Useful for identifying critical spare parts that require special attention ([10]).

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- **Multi-Criteria Classification:**
  - Combines multiple factors like cost, criticality, lead time, and demand forecasting [5, 8, 9].
  - AHP (Analytic Hierarchy Process) is used to assign weights to different criteria and achieve transparent decision-making [8, 10].
  - Machine learning techniques like SVM (Support Vector Machine) are explored for complex multi-criteria classification [9].

Inventory Control Techniques

- **EOQ (Economic Order Quantity):**
  - Determines the optimal order quantity to minimize total inventory holding and ordering costs [2, 7].
  - Requires data on demand, ordering cost, and holding cost per unit [2, 7].
- **ROP (Reorder Point):**
  - The inventory level at which a new order should be placed to avoid stockouts [2, 7].
  - Calculated based on lead time, demand rate, and safety stock [2, 7].

Main Results

- Effective spare parts classification helps optimize inventory control and reduce costs [1, 3, 4, 5, 6].
- ABC analysis is a common and effective classification method, but it can be improved by incorporating additional factors [5, 8, 9].
- EOQ and ROP are valuable tools for determining optimal order quantities and reorder points, leading to efficient inventory management [2, 7].
- Multi-criteria classification and machine learning techniques offer promising advancements in spare parts management, especially for complex scenarios [8, 9].

Inventory Management Strategies in Contemporary Business Environments

Inventory management is a crucial aspect of contemporary business environments, and various studies have explored effective strategies for optimizing inventory levels. Here's a review of key findings from different research papers:

- **Shifting Focus in Inventory Management**

Dinesh Kumar Dhoka et al. [11] observed a shift in focus within the industry, moving beyond traditional metrics such as revenues, profits, top lines and bottom lines to place increasing importance on inventories, working capital and efficiencies. Supply chain management has become increasingly complex due to factors such as globalization, an expanding product portfolio, and decentralization. Researchers discussed the different inventory models and matrices available for monitoring supply chains.

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- **Inventory Classification Methods**

Different inventory classification methods serve different purposes, and researchers have stressed the importance of understanding their limitations and implications before making important decisions based on them [11, 12].

- **ABC Analysis**

A widely used method is ABC analysis, which classifies inventory items into three categories (A, B, and C) based on their annual value consumption. Category A typically represents a small percentage of items that contribute to a large portion of the overall inventory value. Conversely, category C represents a large number of items with a low individual value [12, 15].

- **XYZ Analysis**

Another method is XYZ analysis, which classifies inventory items based on their demand predictability. Category X represents items with steady demand patterns, while Category Y represents items with intermittent demand. Category Z represents items with erratic demand patterns [11, 12].

- **Integration of ABC and XYZ Analysis**

Some researchers recommend combining ABC and XYZ analyses for a more comprehensive approach to inventory classification [11, 13]. This two-dimensional approach considers both the value and predictability of demand, enabling more targeted inventory management strategies.

- **Inventory Management for Spare Parts**

Spare parts inventory management plays a vital role in ensuring the smooth operation of production processes. Here's a summary of research focused on this specific area:

- **Challenges of Spare Parts Inventory Management**

Catarina Teixeira et al. [14] acknowledged the complexity of spare parts inventory management, highlighting challenges related to data collection, the vast amount of information to consider, and the numerous items involved. Spare parts are essential for maintaining the efficient operation of the production process, preventing production and quality losses [14]. However, maintaining high inventory levels comes with associated costs, including capital immobilization and storage space expenses [14].

- **Multi-Criteria Classification for Spare Parts**

Teixeira et al. [14] proposed a multi-criteria classification tool for defining stock management policies for each spare part. The ultimate goal was to provide the organization with a decision-making tool based on quantitative and objective information, enabling them to make informed decisions about holding spare parts in stock [14].

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Inventory Management Systems and Techniques

Technological advancements have led to the development of well-designed software that facilitates inventory management [15]. Here are some key findings from research on inventory management systems and techniques:

- **Inventory Management Techniques**

Sheikh Sajid A.K et al. [15] Addressed various inventory management techniques, including demand forecasting, raw material and commodity asset management, merchandise movement, pricing, and commodity recognition to forecast future demand.

- **Knowledge Models for Inventory Management**

The researchers emphasized the use of knowledge models to define processes and improve inventory management techniques [15]. Specific processes such as VED analysis, inventory audit and Economic Order Quantity (EOQ) are mentioned as part of the knowledge models [15].

- **Economic Order Quantity (EOQ) Method**

Wanthanee Lisa Anjas et al. [17] applied the Economic Order Quantity (EOQ) method to optimize spare parts inventory planning. EOQ is a well-established inventory control method used to determine the optimal number of orders to minimize the total inventory cost [17].

This table summarizes the findings from various research studies on spare parts inventory management and classification techniques.

Table 1: summary of methodology used in the survey and its results

Study	Methodology	Key Findings
[19]	Proposed a new method for optimizing inventory costs while achieving target fill rates for spare parts.	The new method outperformed alternative approaches in terms of inventory cost reduction and ease of calculation.
[20]	Compared two inventory control methods with a company's existing methods to identify the most cost-effective approach.	Continuous review method (S(max inventory level, S (current inventory quantity) resulted in lower storage costs and reduced total inventory costs.
[21]	Focused on applying ABC analysis as an inventory control technique in a service company's spare parts store.	ABC analysis can significantly reduce storage requirements, improve organization, and improve space utilization in spare parts warehouses.
[22]	Systematically reviewed 140 articles on multi-criteria decision analysis (MCDM) in inventory management.	AHP and its fuzzy extension were the most applied multi-criteria methods. Cost, lead time, criticality, item weight, storage space, and item demand were common criteria used.
[23]	Presented a multi-criteria classification methodology such as lead time, price, probability of failure, and annual demand for spare parts management.	Emphasized the need for a multi-criteria perspective to classify spare parts.
[24]	Analyzed and compared the accuracy of three different approaches for inventory item classification.	AI-based techniques (support vector machine (SVM), , and K-nearest neighbours (KNN)) Technique for Order Performance by Similarity to

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		Ideal Solution (TOPSIS) to determine the most accurate ML model for multicriteria inventory item classification yielded better accuracy compared to Multiple Discriminant Analysis (MDA).
[25]	Proposed a framework for inventory classification and management that combines different methods and policies.	Scoring method requires more time and is affected by subjectivity, whereas ABC analysis is easy to explain.
[26]	Compared spare parts classification methods and criteria used in scientific research with those used in industrial companies.	VED analysis is the most adopted classification method, and stock out cost and lead time are perceived as the most important criteria.
[28]	Developed an internal classification system for spare parts to enhance inventory management and maintenance procedures.	Multi-criteria decision-making techniques were used to determine the relative importance of spare parts classification criteria.
[29]	Focused on the multi-criteria classification of spare parts in an Iranian petrochemical company.	The multi-criteria approach provides a more comprehensive understanding of spare parts classification.
[30]	Proposed a data-driven methodology called SP-LACE for spare parts criticality classification.	SP-LACE relies entirely on analysis of objective data typically available in company databases.
[31]	Studied the effectiveness of ABC analysis in a manufacturing company.	ABC analysis is an effective inventory management technique that helps to reduce storage cost, rationalize the number of orders, and reduce overall inventory.

- **Comparison of Inventory Classification Techniques**

Different studies have employed various inventory classification techniques. Here's a comparison of some of the techniques mentioned in the reviewed studies:

Technique	Description	Advantages	Disadvantages
ABC Analysis	Classifies items into A (high value), B (medium value), and C (low value) categories based on their annual usage cost.	Simple to implement, helps prioritize inventory control efforts.	May not be suitable for items with fluctuating demand.
VED Analysis	Classifies items based on their criticality (Vital, Essential, Desirable) to the operation.	Ensures critical items receive the most attention.	Can be subjective in assigning criticality levels.
FSN Analysis	Classifies items based on their frequency (F), severity (S), and novelty (N) of failure.	Considers multiple factors beyond just cost.	Requires more data compared to ABC analysis.
Multi-Criteria Decision Making (MCDM)	Employs various methods (AHP, TOPSIS) to weigh different criteria and rank inventory items.	Provides a comprehensive approach to classification.	Can be complex to implement and may require expert input.

Various studies have employed different inventory classification techniques, including ABC Analysis, VED Analysis, FSN Analysis, and Multi-Criteria Decision Making (MCDM) [11, 12].

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Research has emphasized the importance of understanding the limitations and implications of different inventory classification methods before making important decisions based on them [11, 12]. ABC Analysis, a widely used method, classifies inventory items into three categories (A, B, and C) based on their annual value consumption, with Category A representing a small percentage of items contributing to a large portion of the overall inventory value [12, 15].

Several studies have proposed new methods for optimizing inventory costs, comparing inventory control methods, and applying ABC analysis as an inventory control technique [19, 20, 21]. Multi-criteria classification methodologies have been developed for spare parts management, emphasizing the need for a multi-criteria perspective to classify spare parts [23, 28, 29].

Machine learning techniques, such as Support Vector Machine (SVM), have been explored for complex multi-criteria classification in spare parts management [24,30].

Inventory management plays a vital role in ensuring the smooth operation of production processes, with challenges related to data collection, vast information consideration, and associated costs [14]. Economic Order Quantity (EOQ) has been applied to optimize spare parts inventory planning, aiming to minimize the total inventory cost [17].

Researchers have observed a shift in focus within the industry, placing increasing importance on inventories, working capital, and efficiencies in contemporary business environments [11,15]. This systematic review provides an overview of the key findings and methodologies from various research studies on spare parts inventory management and classification techniques, offering valuable insights into optimizing inventory control and reducing costs in business environments

Summary of survey results

Table 1: Top Authors of spare parts management

Author h	Documents V
Ratnayake, R.M.C.	4
Roda, I.	3
Macchi, M.	3
Antosz, K.	3
Weckman, G.R.	2
Viveros, P.	2
Syntetos, A.A.	2
Sheikh-Zadeh, A.	2
Sgarbossa, F.	2
Saccani, N.	2
Marvel, J.H.	2
Ghuge, S.	2
Fumagalli, L.	2
De Carlo, F.	2
Cantini, A.	2
Akarte, M.	2

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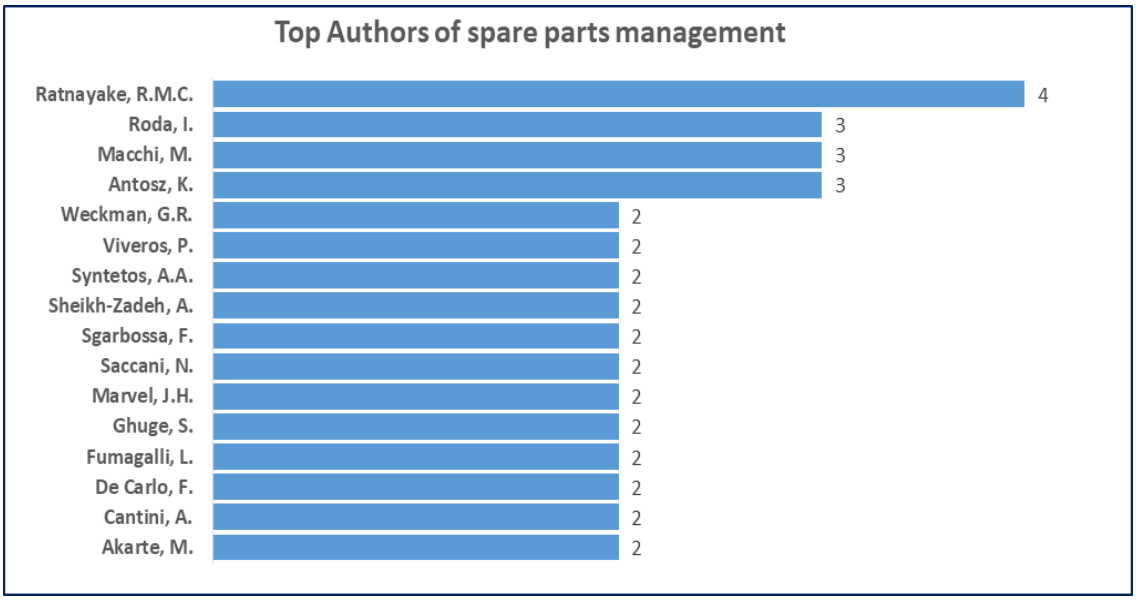

Figure 1: Arrangement of top Authors of spare parts management

According to Scopus data base Fig (1) and Table (1) showing the top authors in research of spare parts classification and management field from 25 years ago that showing that Ratnayake R.M.C is the largest author in the number of papers published in the world in this field of research.

Table 2: Top Affiliation that have papers in the field of research

Document results Affiliation	Documents
Universitetet i Stavanger	4
Politecnico di Milano	4
University of Arkansas	3
Aalborg University	3
Politechnika Rzeszowska im. Ignacego Łukasiewicza	3
Università degli Studi di Modena e Reggio Emilia	2
Universidad Técnica Federico Santa María	2
Jilin University	2
University of Salford	2
Ohio University	2
Norges Teknisk-Naturvitenskapelige Universitet	2
Università degli Studi di Brescia	2
Texas Tech University	2
Università degli Studi di Firenze	2
National Institute of Industrial Engineering	2
Zhejiang University of Technology	2
Gettysburg College	2
Karlsruher Institut für Technologie	2
Rawls College of Business	2
College of Engineering	2

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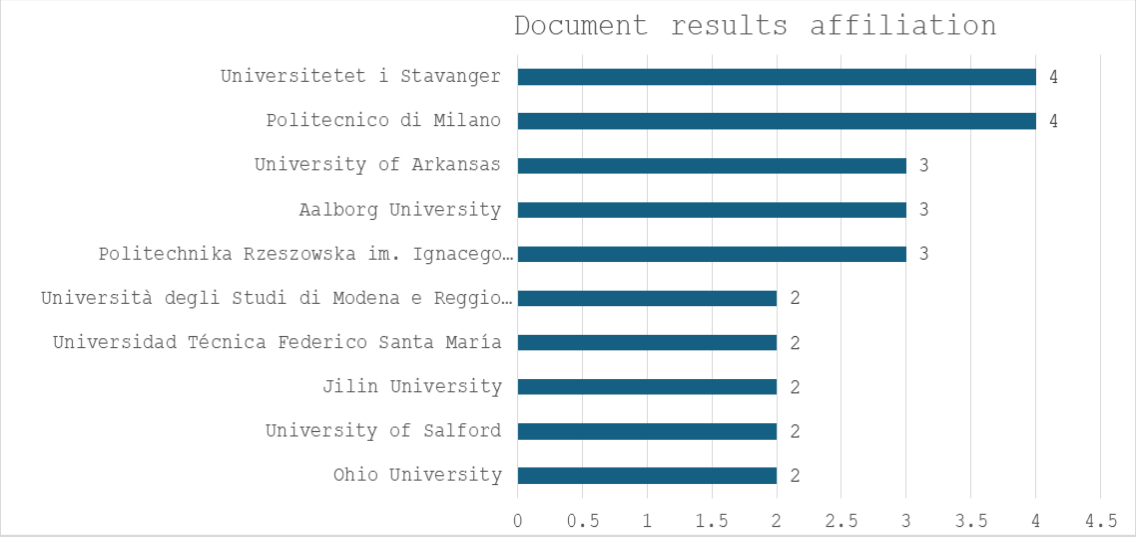

Figure 2: Arrangement of Affiliation of spare parts management

According to Scopus data base Fig (2) and Table (2) showing the top affiliation in research of spare parts classification and management field showing that Universitetet i Stavanger is the largest affiliation in the number of papers published in the world in this field of research.

Table 3: Top Document type in the field of research

Document type	Documents
Conference Paper	69
Article	41
Review	4
Conference Review	1

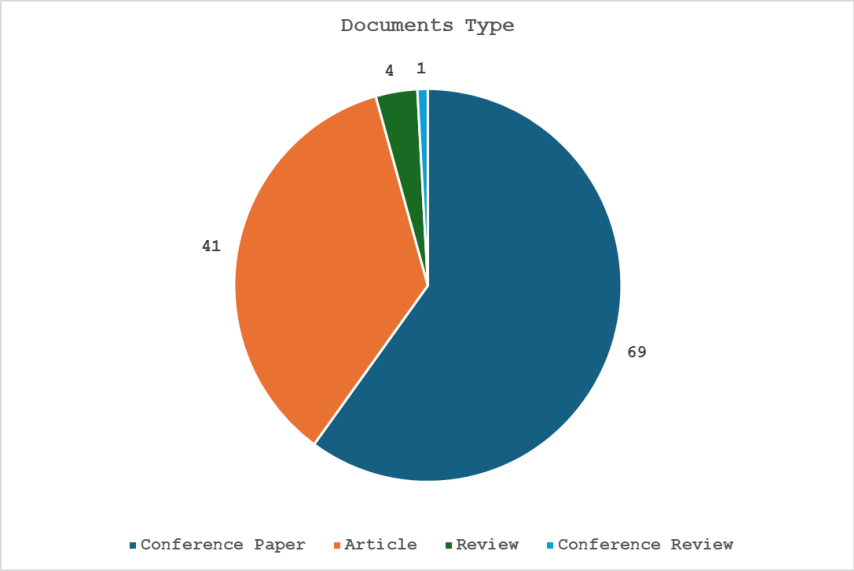

Figure 3: Arrangement of Document types of spare parts management

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According to Scopus data base Fig (2) and Table (2) showing the top affiliation in research of spare parts classification and management field showing that Universitetet i Stavanger is the largest affiliation in the number of papers published in the world in this field of research.

Table 4: Spare parts classification and management through the last 35 years

Year	Documents
2024	2
2023	8
2022	8
2021	7
2020	7
2019	12
2018	9
2017	7
2016	5
2015	8
2014	3
2013	5
2012	6
2011	3
2010	2
2009	2
2008	6
2007	1
2006	3
2005	3
2004	2
2003	0
2002	0
2001	0
2000	1
1999	0
1998	2
1997	0
1996	0
1995	0
1994	1
1993	0
1992	0
1991	0
1990	0
1989	2

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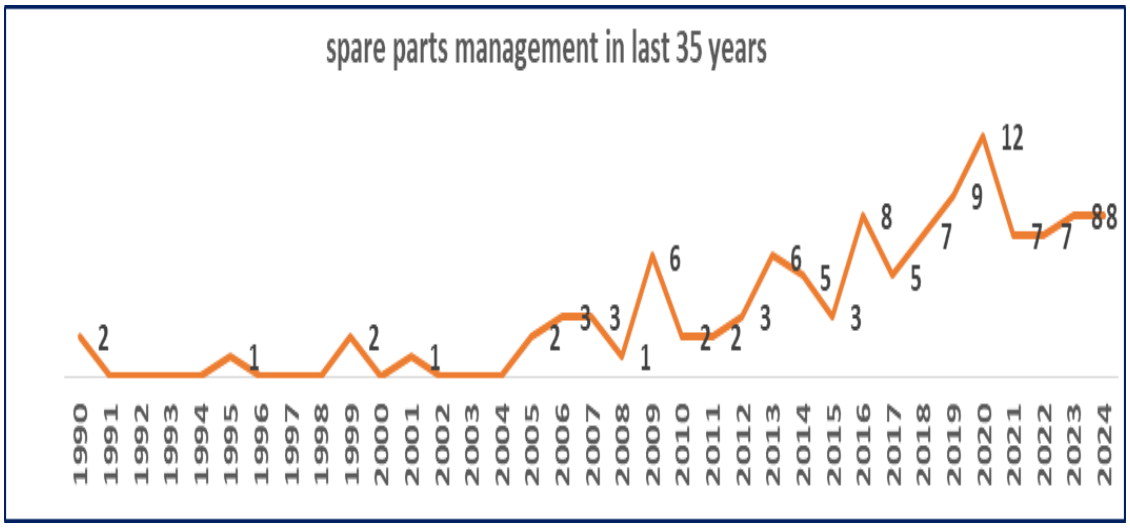

Figure 4: Spare parts classification and management through the last 35 years

According to Scopus data base Fig (4) and Table (4) showing the number of paper published in the world through the last 35 years in research of spare parts classification and management field showing that year 2019 is the biggest year in publishing in the field of research through the last 35 years.

Table 5: Top countries in Spare parts classification and management research

Country	Documents
China	30
United States	14
Italy	11
United Kingdom	8
India	7
Indonesia	6
Norway	6
Germany	5
Turkey	5
Brazil	3
Chile	3
Denmark	3
Poland	3
Portugal	3
Undefined	3
Finland	2
Jordan	2
Mexico	2
South Korea	2
Switzerland	2

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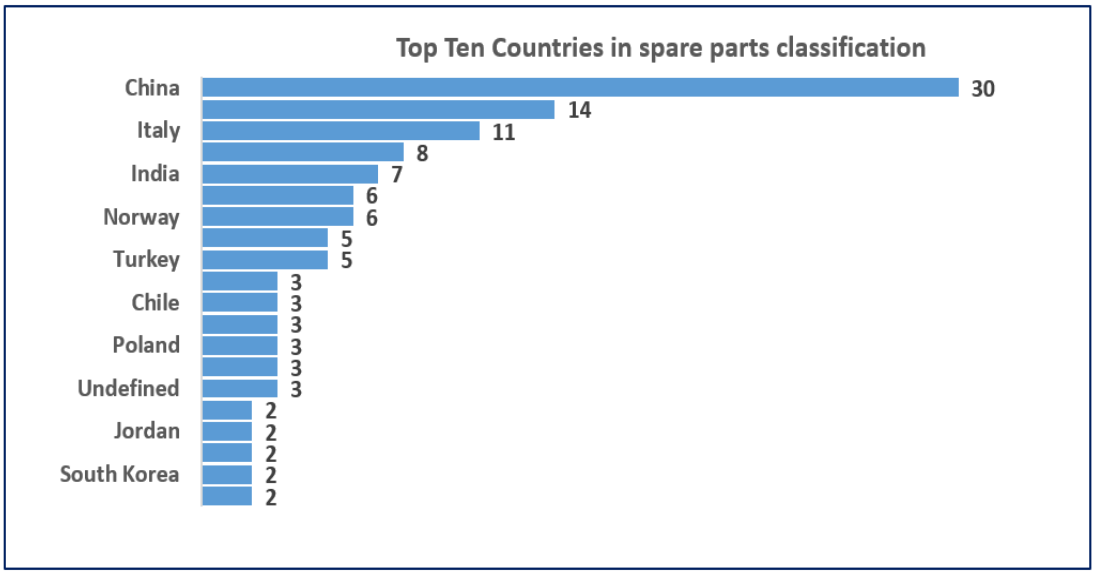

Figure 5**: Top countries in spare parts classification**

According to Scopus data base Fig (5) and Table (5) showing the top countries in Spare parts classification and management research in the world through the last 35 years showing that china is the biggest country publisher papers in the world then the United States of America in publishing in the field of research through the last 35 years.

3. RESULT

3.1 Scientific Gap in the Reviewed Research on Spare Parts Management:

Based on the reviewed research, the major scientific gaps in spare parts management can be summarized as follows:

1. Limited focus on different types of spare parts:

Most research focuses on non-repairable spare parts, while neglecting repairable ones, which present different considerations (e.g., repair cost, lead time).

Research on specific types of spare parts (e.g., critical, non-critical) is limited, despite their varying impact on inventory management and maintenance strategies.

2. Lack of integration across diverse methods:

Existing research predominantly focuses on individual inventory management techniques (e.g., ABC analysis, EOQ) or multi-criteria classification approaches (e.g., SVM-ABC).

Integrating these methods to develop holistic models that account for various factors (e.g., demand forecasting, supplier reliability, cost, criticality) remains underexplored.

3. Insufficient application in specific industries:

While some studies address spare parts management in specific sectors (e.g., aviation, automotive), broader applications across diverse industries are scarce.

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Tailoring existing methods or developing new ones to address the unique challenges of different industries (e.g., complexity of parts, supply chain dynamics) is needed.

4. Underdeveloped data-driven approaches:

Although some research utilizes data mining or machine learning techniques, their full potential for spare parts classification and prediction remains untapped.

Employing advanced data analytics in real-time for dynamic inventory optimization and risk mitigation requires further exploration.

5. Inadequate focus on practical implementation:

Many studies prioritize theoretical frameworks and model development, while neglecting practical implementation strategies. Providing concrete guidelines, decision support systems, or software tools for integrating research findings into real-world applications is crucial. Addressing these gaps could significantly advance the field of spare parts management, leading to more efficient and cost-effective inventory control, improved operational performance, and enhanced customer satisfaction.

3.2. Inventory Classification Methods: Advantages, Disadvantages, and Challenges

There are several inventory classification methods used in different scenarios, each with its own advantages, disadvantages, and challenges. Here's a breakdown of the most common methods:

3.2.1 ABC Analysis:

- **Advantages:**
  1. Simple and easy to understand.
  2. Helps prioritize resources towards high-value items (A-items).
  3. Improves decision-making for ordering, storage, and handling costs.
- **Disadvantages:**
  1. Overlooks demand variability and criticality of items.
  2. May neglect B and C items altogether, leading to potential stockouts or overstocking.
- **Challenges:**
  1. Determining appropriate cut-off points for A, B, and C categories.
  2. Ensuring data accuracy for cost and value calculations.

3.2.2 XYZ Analysis:

- **Advantages:**
  1. Focuses on demand variations, leading to better forecasting and safety stock levels.
  2. Helps with managing fluctuating demand patterns effectively.

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- **Disadvantages:**
  1. Does not consider cost or importance of items.
  2. May be less applicable for products with stable demand.
- **Challenges:**
  1. Interpreting complex demand patterns and categorizing items accurately.
  2. Requiring sufficient historical data for reliable analysis.

3.2.3 VED Analysis:

- **Advantages:**
  1. Prioritizes inventory based on criticality to operations, ensuring business continuity.
  2. Helps prevent downtime and production disruptions.
- **Disadvantages:**
  1. May neglect cost and demand considerations.
  2. Can be subjective in determining criticality levels.
- **Challenges:**
  1. Obtaining accurate information about potential downtime consequences.
  2. Balancing criticality with other inventory management factors.

3.2.4 Challenges of using classification methods for EOQ and ROP:

- Data Accuracy: Rating methods rely on reliable data such as cost, demand, and lead times. Inaccurate data can lead to flawed Economic Order Quantity (EOQ) and Re-Order Point (ROP) calculations.
- Complexity: Integrating classification with EOQ and ROP can be complex, especially for multi-criteria models, which require advanced analysis tools and skills.
- Dynamic Inventory: Inventory can change due to seasonality, promotions, or other factors. The classification needs regular updates to ensure that (EOQ) and ROP calculations remain relevant.

If you provide additional details such as annual usage value, demand patterns, and importance for each component, it can be analyzed how specific classification methods affect EOQ and ROP calculations for inventory production needs.

3.2.5 Choosing the best method:

The optimal classification method depends on your specific needs, data availability, and inventory characteristics.

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These factors are considered.

1. Nature of your inventory: Spare parts, finished goods, raw materials?
2. Available data: Cost, demand, lead times, criticality?
3. Research objectives: Cost reduction, service level improvement, forecasting accuracy?

There's no one-size-fits-all solution. Choose the method that provides the most relevant insights and actionable recommendations for your specific context.

4. THE REASONS FOR CHOOSING THESE METHODS

This is a very comprehensive overview of different inventory management methods and how they are used in spare parts management. The wide range of approaches, is including:

Classification methods:

- ABC analysis: Classifies items based on their annual dollar value, with A items being the most valuable and requiring the most attention.
- XYZ analysis: Classifies items based on their demand variability, with X items having the most predictable demand and Z items having the least predictable demand.
- VED analysis: Classifies items based on their criticality to the overall operation, with V items being the most critical and requiring the most stringent controls.
- ABC-XYZ method: Combines ABC and XYZ analysis to provide a more nuanced classification for spare parts.
- Multi-criteria classification models: Consider various factors beyond just cost or demand, such as reliability, supply characteristics, and part criticality.

Inventory control models:

- Economic Order Quantity (EOQ): Determines the optimal order quantity for an item to minimize total inventory holding and ordering costs.
- Reorder Point (ROP): The level of inventory at which a new order should be placed.
- (R,S,s) policy: A review-based inventory control policy where inventory is reviewed at regular intervals and an order is placed if the inventory level falls below a certain point.
- Just-in-time (JIT): Inventory is delivered just in time for use, minimizing the need for carrying inventory.

Other methods:

- Data mining: Can be used to identify patterns and trends in spare parts data to improve classification and forecasting.
- Decision support systems (DSS): Can provide managers with real-time data and insights to support decision-making.

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Specific examples:

- The study by Wanthanee Prachuabsupak used the Adaboost algorithm to classify spare parts for an OEM, demonstrating its efficacy in reducing storage and procurement costs [1].
- The study by Ni Putu Ayu Nariswaria et al. developed a multi-criteria classification model for aircraft spare parts using the Analytical Hierarchy Process (AHP), resulting in a transparent, rapid, and accurate system [8].
- The study by Buse Atakaya et al. used a combination of ABC, VED, and (R,S,s) analysis to optimize the spare parts inventory management system for a service savings company in the automotive sector [10].

Inclusive, provides a well-rounded understanding of the different methods available for managing spare parts inventory. It is clear that there is no single "best" method, and the optimal approach will depend on the specific needs and constraints of each organization.

5. THE IMPORTANCE OF THIS PART AND ITS PRECEDENCE IN THE RESEARCH

Inventory classification is arguably the most important step in effective inventory management, especially for spare parts, and is the foundation of any successful research in this area. Choosing the best method depends on your specific needs and data, but understanding different methods and their effects is crucial to making informed decisions.

Here's why classification is important:

Improve decision making: By grouping items with similar characteristics, you can tailor your management strategies to suit each group. For example, high-value items will require stricter controls and more accurate forecasting than low-value items.

Reduce resource costs: Categorization helps you prioritize your efforts and focus them on the most important items. This can result in significant cost savings in terms of ordering, storage and handling.

Improved efficiency: When you know where to find items and how to manage them, the entire inventory process becomes more efficient and streamlined. This leads to improved responsiveness to customer needs and reduced lead times.

Better forecasting: Accurate classification facilitates more accurate forecasting of different item groups, resulting in improved inventory levels and reduced risks of out-of-stock or over-stocking.

Data-Driven Insights: Categorization allows you to analyze trends and patterns within each group, providing valuable insights to improve your overall inventory management strategy.

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Now let us discuss the different classification methods used in inventory and spare parts management:

- ABC Analysis: This widely used method ranks items based on their annual dollar value. Items are typically the most valuable and make up the highest percentage of the total inventory value, while C items are the least valuable and make up the lowest percentage. This helps prioritize efforts and resources towards the “A” items.
- XYZ Analysis: This method ranks items based on their demand volatility. Items X have the most predictable demand, while Items Z have the least predictable demand. This helps in forecasting and determining appropriate safety stock levels for each batch.
- VED Analysis: This method ranks items based on their importance to the overall process. V items are vital to operations and should be readily available, while E items are less critical and can tolerate some downtime. This helps in prioritizing items to replenish inventory and ensure business continuity.
- Multi-criteria rating models: These models take into account multiple factors beyond just cost or demand, such as reliability, supply characteristics, and part importance. It can be especially useful for complex inventory systems with diverse items.

Choosing the best method depends on several factors:

The nature of your inventory: Do you deal with spare parts, finished products, raw materials, or a combination of these?

Available data: What data do you have access to about your inventory, such as cost, demand, and lead times?

My research goals: Are you primarily focused on reducing cost, improving service levels, or improving forecast accuracy?

By carefully considering these factors and understanding the strengths and weaknesses of each classification method, you can choose the approach that best suits your specific research needs.

6. DATA ANALYSIS AND THE RESEARCHERS’ OPINION

The researchers used multi-criteria decision-making techniques to determine the relative importance of spare parts classification criteria. However, a potential scientific gap in the research lies in the limited sample size of spare parts analyzed.

To enhance the study's robustness and applicability, future research could expand the sample size to include a broader range of spare parts from different equipment types or industries. Overall, the study provides valuable insights into spare parts classification and the importance of considering multiple criteria in the decision-making process.

However, it is important to note that the findings may not be generalizable to all industries or equipment types, and further research is needed to validate the proposed framework.

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7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Based on the literature review conducted in the paper, the major scientific gaps in spare parts management can be summarized as follows:

1. Limited focus on different types of spare parts: The reviewed research has a limited focus on different types of spare parts, which can lead to inaccurate forecasting and inefficient inventory management.
2. Lack of integration of multivariate time series: The reviewed research lacks integration of multivariate time series, which can lead to inaccurate forecasting and inefficient inventory management.
3. Limited focus on the impact of disruptions: The reviewed research has a limited focus on the impact of disruptions, which can lead to inefficient inventory management and increased storage costs.

7.2 Recommendations

To address these gaps, the paper proposes new features that allow dependencies and interactions among the variables of multivariate time series to improve prediction accuracy. The paper also recommends the integration of qualitative and quantitative methods, such as VED analysis, analytical hierarchical process (AHP), and e-constraint optimization methods, to identify and prioritize spare parts to be stocked efficiently.

The paper emphasizes the importance of effective spare parts management in optimizing storage costs and ensuring the availability of raw materials and products. The proposed hybrid approach can help companies achieve cost savings and reduce total inventory costs, making it a suitable choice for inventory control strategy.

Overall, the paper provides insights and actionable recommendations for effective spare parts management in different contexts, considering the specific needs and challenges of each industry. By addressing the scientific gaps and building on existing knowledge, companies can develop more effective methods for spare parts management and ensure the smooth operation of production processes.

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