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REVIEW

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Machine learning-driven optimization of enterprise resource planning (ERP) systems: a comprehensive review

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Abstract

In the dynamic and changing realm of technology and business operations, staying abreast of recent trends is paramount. This review evaluates the progress in the development of the integration of machine learning (ML) with enterprise resource planning (ERP) systems, revealing the impact of these trends on the ERP optimization. In recent years, there has been a significant advancement in the integration of ML technology within ERP environments. ML algorithms characterized by their ability to extract intricate patterns from vast datasets are being harnessed to enable ERP systems to make more accurate predictions and data-driven decisions. Therefore, ML enables ERP systems to adapt dynamically based on real-time insights, resulting in enhanced efficiency and adaptability. Furthermore, organizations are increasingly looking for artificial intelligence (AI) solutions as they actually try to make ML models within ERP clear and comprehensible for stakeholders. These solutions enable ERP systems to process and act on data as it flows in, due to the utilization of ML models, which enables enterprises to react effectively to changing circumstances. The rapid insights and useful intelligence offered by this trend have had a significant impact across industries. IoT (Internet of Things) and ML integration with ERP are continuously gaining significance. These algorithms allow for the creation of adaptable strategies supported by ongoing learning and data-driven optimization, which has a number of benefits for ERP system optimization. In addition, the Industrial Internet of Things (IIoT) was investigated in this review to provide the state-of-the-art and emerging challenges due to ML integration. This review provides a comprehensive analysis of the integration of machine learning algorithms across several ERP applications by conducting an extensive literature assessment of recent publications. By synthesizing the latest research findings, this comprehensive review provides an in-depth analysis of the cutting-edge techniques and recent advancements in the context of machine learning (ML)-driven optimization of enterprise resource planning (ERP) systems. It not only provides an insight into the methodology and impact of the state-of-the-art but also offers valuable insights into where the future of ML in ERP may lead, propelling ERP systems into a new era of intelligence, efficiency, and innovation.

Keywords Enterprise resource planning, Machine learning, Optimization, IIoT state-of-the-art techniques

1 Background

The use of machine learning (ML) in enterprise resource planning (ERP) systems is a top priority of technical advancement in today's data-driven corporate environment. The primary concern of this in-depth investigation is to investigate extensively the complex world of ML-driven ERP improvement. This review has been divided into several sections, each tackling key aspects of this integration in order to offer clarity for future

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development. ERP systems are multidimensional software solutions made up of modules or applications, each of which caters to a different company function. Accounting, human resources, supply chain management, manufacturing, sales, and customer relationship management (CRM) are among the most often utilized modules, according to recent reviews. These systems are made up of a number of crucial elements that cooperate to promote effective and data-driven management. Additionally, ERP systems come with reporting and analytics capabilities that let users create personalized reports, view data, and discover how well their businesses are performing.

Traditional ERP [1] systems have been critical in simplifying corporate operations in the modern global economy; nonetheless, they are not without faults and have more obvious drawbacks as the business environment changes; however, research has repeatedly demonstrated that these limitations could be explained regarding:

- The process requires costly software licensing, hardware infrastructure, customization, training, and continuous maintenance.
- ERP systems may need substantial customization to fit with a company's particular business procedures. Longer implementation periods and greater costs may be the results of this complexity.

ERP, in contrast, has both strategic and tactical effects [1]. Strategical effects will have an impact on the company's strategic decisions and on its future business. On a management and operational level, tactical effects will have an impact on how the company conducts its internal business. However, modern ERP systems demand integration with other systems including those of suppliers, customers, and third-party applications. This relationship improves accessibility and data exchange.

Since the beginning, ERP systems have encountered significant changes and have influenced contemporary corporate processes [1]. Material requirements planning (MRP) systems, which first appeared in the 1960s, are where the origins of ERP systems could be located. These early systems were primarily concerned with meeting the production and inventory requirements of manufacturing firms. By maximizing material needs, MRP systems assisted firms in planning and managing their manufacturing processes more effectively.

MRP II systems introduced a new generation in the 1980s, with expanded features such as finance management, production scheduling, and capacity planning. The goal of MRP II systems was to bring together multiple organizational areas for more comprehensive planning and decision-making. In addition to these key historical eras, the phrase "enterprise resource planning" (ERP) became well-known in the 1990s, when ERP systems went beyond manufacturing to include all essential business operations, including finance, human resources, procurement, and more. ERP systems sought to offer a single, integrated platform that would unify data and expedite procedures inside a business.

ERP II solutions [1] were developed in the 2000s to support e-business and e-commerce activities. These systems placed a strong emphasis on connectivity with suppliers and customers as well as cooperation and real-time data exchange. ERP II systems gave businesses the tools for online transactions, supply chain visibility, and customer relationship management that they needed to adapt to the digital age.

Until the Cloud-Based ERP [2] and Mobile Accessibility (2010–2020s) that offered scalability, flexibility, and lower IT infrastructure costs, as a common feature, mobile accessibility now enables clients to access ERP data and features via smartphones and tablets, improving real-time decision-making.

According to the analysis of the efficiency measurement results in [3], the decision-making unit became more efficient after the deployment of ERP. Nonetheless, the incorporation of ML into ERP systems is a reaction to the growing business environment, which is characterized by big data, IoT, and the need for informed decision support. Enterprise resource planning (ERP) systems serve as the foundation of organizational operations in today's corporate environment by simplifying procedures and maximizing resources. These systems' seamless technological integration has increased their effectiveness while also opening up a wide range of new opportunities. Among these, machine learning (ML) has become a ground-breaking paradigm that is transforming how we view and use ERP systems. ML approaches have the ability to convert ERPs into intelligent, adaptable, and decision-supportive platforms by utilizing the strength of data-driven insights and predictive analytics. For instance, paper [4] goes into further detail on how ERP supports auditing procedures, including the advantages and disadvantages of using ERP for auditing. Furthermore, future research would focus on the audit process's overall influence on growing technology innovations.

However, using machine learning in ERP systems can be challenging for organizations. There are different problems they may encounter, like complicated algorithms and issues with the accuracy of the data. To fully utilize the synergy between ML and ERP, it is essential to comprehend the intricacies of these issues and investigate strategies to address them. This study starts with an investigation of machine learning and ERP interaction and attempts to find new methods to overcome the problems businesses face. This review aims to offer a comprehensive overview of the environment by closely examining the methodology used and the challenges encountered. Additionally, it highlights the substantial advantages that businesses adopting ML-driven ERP optimization may have, such as improved functionality and the ability to make data-driven decisions. By taking into account factors like equipment availability, raw material availability, and production prices, ML models improve production schedules. They reduce resource waste and production interruptions. The workforce engineering tries to reduce the expense and time required to complete a task.

In [5] an assistance system is provided to assist sales engineers in making suggestions on new goods and services that may be marketed to their clients. We've reviewed the latest research papers that involve state-of-the-art integration of ML and ERP systems throughout this deep review investigation. A step toward a more intelligent and adaptable organizational structure is represented in multiple aspects one of them the predictive analytics. This work explores current developments and new trends as well, foreseeing the future directions of this dynamic scientific field.

The combination of machine learning with enterprise resource planning systems offers not just efficiency but also a fundamental in how firms operate, strategize, and prosper in the digital age. Although there exists considerable research regarding the use of ML algorithms in ERP, the state-of-the-art investigation in this work provides an overview that contributes to the knowledge base of information systems and the entire enterprise management systems.

The aim of this review is to conduct a comprehensive investigation of the body of knowledge about the integration of machine learning (ML) techniques into enterprise resource planning (ERP) systems. To leverage answering the specific research question of how machine learning techniques can effectively be harnessed to optimize enterprise resource planning (ERP) systems, and what are the associated challenges, benefits, and emerging trends? The methodology of finding pertinent research studies, journals, and articles in this area constitutes a component of this topic. Reputable sources, including academic databases and journal databases, are used to compile pertinent information. Thus, the chosen information covers both historical and contemporary trends, guaranteeing a thorough comprehension of the topic. ML applications inside ERP were carefully divided into categories based on functionality and sectors. Consequently, this review provides a clear picture of the heterogeneous ML-driven ERP improvement environment.

This review started with background and context section, where we establish the context, starting with exploring how data-driven decision-making has become pivotal for enterprises in responding to market changes and making informed choices. Subsequently, we delve into machine learning, offering an overview of its core concepts and methodologies. Moving forward, we explore how ML seamlessly integrates with ERP systems, ushering in unprecedented levels of efficiency and productivity. Within this work, we examine various ML-enhanced features such as inventory management, production scheduling, quality control, and predictive maintenance. Lastly, we explore adaptive process automation and its transformative impact on workflow optimization. By structuring our review, we aim to provide a comprehensive and coherent examination of the landscape of ML-driven ERP optimization, offering insights into recent advancements and emerging trends that hold the potential to reshape the future of enterprise technology.

2 Main text

2.1 Methodology and scope

In this section, we outline the scope and methodology, setting the stage for a comprehensive exploration of the integration of machine learning (ML) with enterprise resource planning (ERP) systems. Using a strict approach, this review sought to give academics and businesses a thorough, up-to-date and informative examination of integration of the machine learning techniques into enterprise resource planning systems.

To highlight the methodology, and state-of-the-art, research scope and define the challenges, a comprehensive analysis approach was used. Consequently, the relevance of the papers chosen took a vital role, focusing on ML applications in ERP systems, although it is one of the selection criteria. while, the second is the conventional method of publication, where peer-reviewed journals, conference proceedings, and scholarly articles were prioritized to ensure the accuracy of the data. Recent papers were given preference. The review concluded with the identification of emerging trends, challenges and prospects in the integration of ML in ERP systems. This review's scope covers a wide range of topics related to ML-driven ERP innovation. It encompasses the following areas, without being restricted to them:

- Problems and difficulties with ML integration in ERP systems.
- Industries and use cases where ML-driven ERP optimization has been implemented, including manufacturing, inventory and energy.

- The potential advantages of ML in terms of improved decision-making, cost savings, operational efficiency, and sustainability.
- Emerging patterns and potential avenues for ML-ERP integration.

Nevertheless, integrating machine learning algorithms into ERP systems provides decision-makers with valuable insights that help enterprises make better decisions.

The contribution of this research work lies in its systematic literature review methodology. This review extends our knowledge by employing rigorous review techniques, it offers a comprehensive and well-structured analysis of the integration of machine learning (ML) in enterprise resource planning (ERP) systems. The methodology ensures the reliability and depth of the analysis, providing readers with a clear understanding of the current state-of-the-art in this dynamic field.

Additionally, through the systematic literature review, we contribute to a deeper understanding of how ML techniques are harnessed within ERP systems. The study was conducted in the form of a review, with data being gathered by exploring the wide range of publications, methodologies, challenges, and benefits, shedding light on the multifaceted relationship between ML and ERP.

As a result, readers gain insights into this integration and its implications for modern businesses. Also, the identification of emerging trends within the ML-driven optimization of ERP systems considered as a significant contribution. In addition, this review serves as a valuable resource for researchers, practitioners, and decision-makers seeking to explore the possibilities of ML within ERP systems. By presenting an overview of applications across various ERP modules, such as inventory management, customer relationship management (CRM), and supplier relationship management (SRM). This guidance can catalyze further advancements in the field, ultimately benefiting industries and businesses.

2.2 Machine learning in enterprise technology

This subsection delves into the applications of ML in various aspects of enterprise technology, from data-driven decision-making to enhancing the functionalities of ERP systems. Machine learning (ML) is a subset of artificial intelligence that enables computers to learn from data without having to be explicitly programmed. ML algorithms have the ability to quickly and precisely evaluate enormous volumes of data when connected with an ERP system. This implies that based on current statistics, decision-makers are able to make well-informed decisions. Further, key performance indicators (KPIs) will be developed utilizing data mining and machine learning and will be predictive in nature. Hence, software may learn from data and make predictions or decisions using machine learning algorithms without having to be explicitly programmed.

According to [6], the implemented methods of analysis will enhance machine learning capabilities to provide recommendations on new products for users based on service support systems to effectively monitor various KPIs related to business and aid in their decisions. The system only provides an end-to-end recommendation based on KPIs from customer relationship management. Traditionally, ERP systems are software applications that help organizations manage and supervise their diverse activities. Tasks like inventory management, accounting, human resources, and customer relationship management are made easier with the use of these technologies. Enterprise information systems (EISs) are able to sense, detect, analyze, or recognize more and more, even going beyond the range of human cognition, and then react based on that understanding [7]. ERP usage in businesses saves time and costs by eliminating the need for several software packages or manual data input by combining all of these activities into a single system. Using ERP systems, it is possible to manage vital resources like cash and human resources. Cost reductions are produced by ERP resource optimization [8].

Furthermore, the integration of these two technologies results in more effective and efficient collaborative operations. For instance, real-time analysis of massive volumes of data using ML algorithms alongside ERP platforms is possible. Having more informed decisions on issues like inventory management or customer service [9] enhances data-driven process creation in order to generate an evidence-based decision support tool for business process management. Thus, AI and ML usage serve a more significant part in novel endeavors as the analytical techniques and decision intelligence further include modeling enhancement and decision-making process. Besides, this integration attempts to facilitate digital transformation and the conversion of production into adaptable manufacturing systems, thereby improving business agility.

The management function is based on planning in general and planning in enterprises in particular. In order to economically justify the outcomes obtained, the authors of [8] automated the production planning process based on the ERP system. Implementation of the SAPERP system's automated "production" process planning unit results in a decrease in the amount of time needed to maintain the production planning process, improved production process management, lower costs, and an increase in overall enterprise productivity and investment appeal. According to the difficult issues that many firms have faced in recent years, the study presented in the paper [8] was carried out utilizing a comparative analysis of the primary enterprise architecture frameworks, highlighting the advantages and disadvantages of each. While the majority of the conclusions concern what and how things should be done, article [2] explored four of the most well-known frameworks in order to provide further insight into the various business architectural elements. It emphasizes the thorough measurement strategy to evaluate the total value contribution of some of the primary enterprise architecture frameworks.

2.2.1 Data-driven decision-making in responding to market changes

ERP systems' significance in corporate operations arises from their ability to minimize business procedures, and encourage cross-functional cooperation, all of which boost productivity, cut down on effort duplication and enhance decision-making. Correspondingly, data-driven decision-making involves making decisions that are well-informed and based on data analysis. In order to comprehend market trends, consumer, behavior, and other elements that have an impact on corporate operations, this strategy involves gathering and assessing pertinent data. Businesses may better adapt to market changes by utilizing data to guide their actions.

Likewise, domain knowledge improvement for service engineers [5] through the product and services recommender system provides an IIoT analytic system that proposes new prospective sales, up-sales, and cross-sales of products and/or services. This method also promotes the exchange of business expertise among salespeople and increases the creation of sales possibilities in their customer portfolio by enhancing the cooperation of their subject knowledge.

The system does not make decisions instead of the user; rather, it equips them with the tools they need to make better informed and data-driven decisions about the products they are presenting to clients.

Alternatively, relying on optimizing processes and resources, ERP systems help organizations reduce operational costs, minimize waste, and improve resource allocation. Businesses that leverage ERP systems gain a competitive edge by responding more swiftly to market changes, customer demands, and emerging opportunities.

The consequences of integrating machine learning algorithms into an ERP system provide decision-makers with valuable insights that help them make better decisions. In [10] the automation of maintenance decision processes for Industry 4.0 integrated manufacturing applications was the main focus. Data-driven decision-making is a process of making informed choices based on the analysis of data, which involves collecting and analyzing relevant information to understand market trends, customer behavior, and other factors that affect business operations. By using data to inform decisions, businesses can respond more effectively to changes in the market.

An organization-prospective ERP system with integrated customer relationship management (CRM) and supplier relationship management (SRM) modules enables organizations to better manage their relationships with customers and suppliers. Many ERP providers, including Oracle, have been progressively integrating ML and AI technologies into their ERP systems to enhance various functionalities. These technologies are used for predictive analytics, automation, data analysis, and decision support within ERP processes. This approach came as a factor which took a role in the increase of the overall revenue in addition to the illustrated increment in the workforce. The integration of ML and advanced technologies into SAP's ERP systems, as well, contributed to the company's competitiveness and customer satisfaction, although it's just one element of SAP's overall business strategy [11].

In view of all that has been mentioned so far, one may suppose that the major benefits of an ERP system are fewer effective products, process integration, better forecasting and planning, formalization of the business operations of the organization, and protection against operational mistakes [8], while the drawbacks include opposition and the owners of the firms' mistrust of high-tech solutions [8]. On the other hand, the innovative Graduation Intelligent Manufacturing System (GiMS) with synchronization-oriented manufacturing planning and control (MPC) for Industry 4.0 manufacturing is then examined in [12] paper, which summarizes the development of MPC systems with enabling technologies and the altering business climate at that time. Examined cutting-edge MPC designs and methods for manufacturing with Industry 4.0. A method for developing and utilizing a predictive maintenance platform in automobile manufacturing has been described in [13]. Its methodology is not specific to the automobile sector; rather, it can be applied to other industries and to both new and existing machinery.

In addition, a comprehensive approach to assess the identified challenges for adopting the BDA into IIoT systems in the context of industry 4.0 was developed in [14]. The obtained results confirmed the efficiency, stability, and reliability of the proposed method.

2.2.2 Leveraging data for informed decisions

Data-driven decision-making is the cornerstone of ML in the enterprise landscape. Here, we examine how ML algorithms enhance decision-making by responding to dynamic market changes. Modern ERP systems now have dominant analytics, AI, and machine learning capabilities, enabling businesses to gather useful insights, forecast trends, and encourage innovation. ERP systems are anticipated to progressively adapt as technology develops and plays a crucial part in the digital transformation of enterprises. ERP systems are used in the industrial sector to increase productivity [15] by tracking supply, requests, scheduling, finished inventory products, and other essential information required for management, ERP systems are capable of regulating every aspect of enterprise. Numerous issues may be solved by ML integration in ERP.

ERP system solution, taking into account the issues with AI and ML integration into ERP, is attempting to develop solutions by outlining the challenges, identifying potential risks, and offering predictive maintenance. Furthermore, machine learning paired with an ERP system technology will deliver highly comprehensive forecasting insights. The selection of an ML technique for enterprise resource planning (ERP) system optimization relies on the particular use case that has to be optimized; Fig. 1 summarizes several of these algorithms and their applications in ERP optimization for the selected use cases. As well as some of their latest innovative applications are compared in [16]. The existing body of research pertaining to review methodology has extensively explored the potential benefits and challenges associated with its integration. Table 1 presents the machine learning approaches used and the corresponding outcomes in the selected use case.

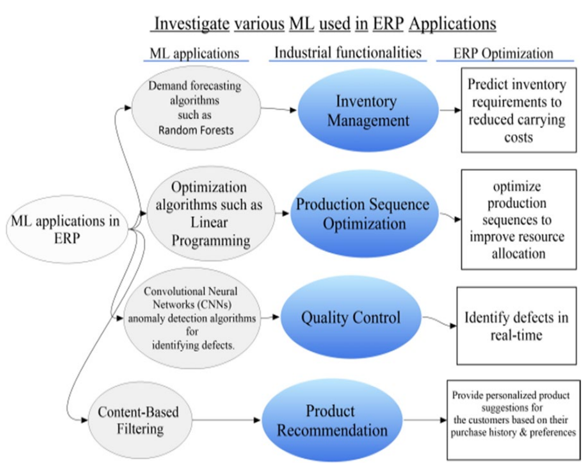

Fig. 1 Selected ML algorithms along with the functionalities used in ERP applications

Despite the presence of challenges related to data accuracy, algorithmic complexity, and setup complexities, the integration of Industrial Internet of Things (IIoT) and machine learning (ML) within the enterprise resource planning (ERP) environment has yielded remarkable outcomes in terms of increased productivity, cost savings, and improved decision-making.

These outcomes underscore the immense value of incorporating IIoT and ML within the ERP framework. The results of this study provide a foundation for a prospective scenario whereby intelligent and data-oriented enterprise resource planning (ERP) systems become indispensable assets in the fiercely competitive global market, as organizations persist in their efforts to adapt to the digital age.

To minimize delay and reduce maintenance costs, machine learning algorithms examine sensor data from equipment to forecast whenever repair is expected, which directly affects the lengthening of equipment lifespan, lowering maintenance costs, and boosting the equipment uptime. In addition, [17] paper's goal was to provide a general overview of ML-enabled predictive maintenance (PdM) in automotive applications to readers from a wide

Table 1 Selected use case from the literature with the corresponding outcome

References	Use case	Outcome
[18]	Applications fields for AI in PLM	An investigation to the sophisticate applications of AI in the context of PLM
[19]	Leverage AI technologies in BIM	A comprehensive review of the current development and future directions regarding the BIM-AI integration in the construction field
[20]	Implementation of artificial intelligence (AI) in enterprise resource planning (ERP) modules	AI enters the algorithms embedded in the various modules of ERP systems
[21]	Implementations of AI in the ERP	AI in ERP is used in a variety of deployment situations, including CRM, SCM, PLM, HR, and financial management
[22]	ML and production planning and control (PPC)	It integrates versatility of machine learning (ML) and production planning and control (PPC) to simplify the incorporation of ML algorithms into the DTs of production systems
[23]	Intelligent manufacturing	This essay discusses the significance of AI in smart manufacturing, drawing on past studies conducted by the author
[24]	Digital twin	The digital twin method "ontology-based modeling," which assembles with data entry minimization, and prerequisites for analysis

range of backgrounds. It underwent a thorough review of the literature that included 62 publications on ML application cases. It suggested future studies, according to the author which may focus on how generic PdM advancements apply to use cases in the automobile industry, whereas businesses can keep ahead of the curve by regularly evaluating and adjusting their strategies in response to economic developments by using a data-driven approach. They get essential knowledge that helps them make wise decisions and eventually propels them to success in the competitive market of today.

2.3 The integration of machine learning with ERP

This subsection provides an overview of the integration of ML with ERP, highlighting its transformative impact on enterprise systems. Machine learning (ML) applications within enterprise resource planning (ERP) systems have ushered in a transformative era for businesses. One of the key applications lies in predictive analytics, where ML algorithms analyze historical data to forecast trends and demand patterns. This capability enables businesses to optimize inventory levels, anticipate customer needs, and streamline supply chain operations.

Additionally, ML-driven anomaly detection enhances cybersecurity measures by identifying irregular patterns in data, safeguarding sensitive information from potential threats. Moreover, the integration of machine learning with ERP systems is a multidimensional process. Further this will enhance data analysis, enabling businesses to gain actionable insights from massive datasets. By processing vast amounts of information in real time, ML-powered ERPs facilitate dynamic decision-making, empowering organizations to respond swiftly to market changes.

Furthermore, machine learning algorithms enhance personalization within ERP interfaces, tailoring user experiences based on historical interactions and preferences. This level of customization not only boosts user satisfaction but also augments overall system efficiency. Ultimately, the synergy between ML and ERP redefines traditional business processes, creating intelligent, adaptive systems that pave the way for a more efficient, responsive, and innovative organizational future.

ERP systems are capable of automating time-consuming, repetitive operations using some sort of machine learning algorithm. In the long run, this would save time and assist in reducing human error. Some of the industrial advancements that integrate machine learning into ERP systems enable businesses to make use of data's potential for more intelligent, data-driven decisions, improved operational efficiency, and a competitive edge in the dynamic business environment.

As a result, Industry 4.0 concentrates on how technology is changing industries. Automation, data interchange, and smart manufacturing goals are all in accord with the aims of ML integration in ERP. For instance, predictive maintenance is essential for avoiding costly breakdowns and simplifying maintenance cycles in a variety of sectors. An overview of intelligent manufacturing techniques is provided in [25], which also expands on research on the shift from discrete to intelligent manufacturing.

According to [26] enterprise data collected through a survey that examined the relationships of an enterprise's strategy orientation, digital transformation capability, and operational performance, digital transformation capability will enable enterprises to integrate their business processes and routines through digital technology to gain a competitive advantage.

The goal of [27] was to execute digital strategies and transformation needs, and the findings revealed that, although technical competencies come largely from on-the-job training, epistemological competencies are insufficient and require more substantial consideration and training. Also, [28] study enhanced the IoT sensor networks with a proof-of-concept heating, ventilation, and air conditioning plant using a preventative maintenance technique. The findings demonstrated the applicability of the developed building structures preventive maintenance technique and the combined IoT and BIM dashboard system.

A data-driven approach to sourcing and inventory management for SMEs was proposed in [29]. It improved the use of artificial intelligence (AI) and fuzzy inference systems (FIS) instead of conventional inventory models. The results show how well the suggested approach performs in giving SMEs decision support solutions in the face of uncertainty. Hence, enhanced product quality, reduced defects, and minimized rework [30]. Supplier risk management, ML-based image recognition and sensor data analysis can identify defects and anomalies in real time during the manufacturing process. A considerable amount of literature involved the investigation of ML integration and application in ERP, as selected and illustrated in Table 1.

2.4 Functionalities enhanced by ML in ERP

We explore the specific functionalities within ERP that are enriched through the integration of ML, setting the stage for in-depth analysis. ERP systems would use a vital ML algorithm to automate repetitive and time-consuming tasks. This might include quality control, inventory management, and production recommendations through the use of machine learning algorithms within an ERP system. Companies may save time, eliminate mistakes, and enhance the process by automating these sorts of processes using machine learning algorithms incorporated into an ERP system. The enhanced functions via ML and ERP connection are listed in Table 2.

In view of this, [31] explored artificial intelligence strategies for solving challenges in communication networks. The suggested deep learning algorithm for IoT prediction was built at edge computing, it has done IoT traffic prediction techniques based on deep learning, and the prediction accuracy was reviewed and tested. However, firms may avoid making instantaneous decisions based on unreliable data by using data-driven decision-making. When reacting to market developments, businesses may use insights from a variety of sources, including consumer feedback and social media analytics, rather than just intuition or prior experiences. By evaluating historical data and patterns to make predictions or automate tasks, state-of-the-art machine learning algorithms and models are being implemented into ERP systems to improve decision-making processes.

2.4.1 Inventory management and demand forecasting enhancement by ML

Within ERP, ML enhances inventory management, streamlines demand forecasting, and even augments human resources functions. We delve into these enhancements; in order to estimate demand accurately, machine learning algorithms examine external variables and past sales data. This causes lower carrying costs and optimizes inventory levels.

On the other hand, we optimize inventory management and control in the ERP environment and propose specific solutions and corresponding development measures; [32] analyzes the issues and causes of inventory management and human resource management in the ERP environment. This analysis was done to help businesses achieve reasonable inventory control and boost their competitiveness in the market. The processing effectiveness is better after system optimization, and the inventory may be adjusted to encourage resource conservation. Additionally, in [29] utilization of hybrid GN-ANN approach is used in the development of a DSS for sourcing and inventory management in SMEs that have limited resources and knowledge.

In this review paper, we present an overview of the usage of machine learning algorithms in various IoT use cases, which is explicitly given in Table 3 that illustrates the state-of-the-art methodologies along with its pros and cons, while the functionality of ERP is shown in Fig. 1 and Table 2, with supporting use case scenarios. The present gaps in machine learning and IoT integration were examined to identify difficulties and future prospects.

2.4.2 Production scheduling and optimization

ML-driven production scheduling and optimization is vital for operational excellence. This section delves into the use of ML in these domains. This subsection's thorough examination has highlighted how ML algorithms enable industrial processes to adjust to real-time data and act quickly in response to changes in demand and supply. The end result not only reduces downtime and resource waste, but also has the potential to increase competitiveness in a market that is becoming more dynamic. Design is more sustainable, robust production planning and control (PPC) systems by integrating management approaches, along with their specific tools and procedures, with I4.0 technologies, such as the IIoT and the DT. We integrate data analytics and machine learning into PPC I4.0 to handle difficult issues automatically and autonomously, and create novel optimization, simulation, and artificial intelligence models and algorithms to assist PPC systems [33].

A significant field in the context of the machine learning (ML) integration with enterprise resource planning (ERP) systems is the scheduling and optimization of production. This goes into the core of the manufacturing process, where complex equipment, resources, and timetables must work together for productive and economic output.

Table 2 Functionalities enhanced by ML algorithms and ERP integration

Functionality	Methodology	ML algorithm
Demand forecasting [39]	Time-series analysis, deep learning models	LSTM
Predictive maintenance [30]	Sensor data analysis, predictive modeling	Random forest, LSTM, decision trees
Supply chain optimization [40]	Predictive analytics, optimization models	Genetic algorithms, Linear programming
Inventory management [41]	Demand forecasting	Reinforcement learning
Customer segmentation in CRM [2]	Clustering techniques, Customer behavior analysis	K-Means, Neural networks
Fraud detection [5]	Anomaly detection, pattern recognition	Isolation forest, Auto-encoders, One-class SVM
Production process optimization [17]	Reinforcement learning, Process simulation	Simulation models

Table 3 Use cases in IIoT field and the used ML algorithms with description of pros and cons

Use case	IIoT field	ML algorithm	Pros & Cons
Predictive maintenance [48]	Industrial field	LSTM, CNN	Pros: Anticipates equipment failures, reducing downtime and maintenance costs Cons: Requires substantial historical data, the possibility of false alarms or missed predictions
Quality control [49]	Manufacturing	SVM, neural networks, decision trees	Pros: Enhances product quality, reduces defects, ensures real-time monitoring Cons: Initial training complexity, need for consistent data quality, the potential need for retraining
Supply chain management [50]	Logistics, manufacturing	Reinforcement learning	Pros: Optimizes inventory, reduces costs, enhances delivery efficiency Cons: Sensitive to data quality, requires fine-tuning for specific industries
Process automation [23]	Manufacturing	Deep learning, natural language	Pros: Reduces errors, enhances overall efficiency Cons: integration challenges,
Predictive analytics [22]	Various	time-series analyses, anomaly detection	Pros: Improves decision-making Cons: Challenges in data pre-processing

It is a real paradigm shift for companies, and the transition to Industry 4.0 impacts their entire operation, namely the production chain, the organization of work, the economy of the company, the management and business logistics, business strategy, and consumer habits [34]. All the sensors and data management via the cloud make it possible to follow the product in its life cycle; This challenges the current product/service divide in product tracking.

Production scheduling, which has long been problematic in various industries, from food processing to the production of vehicles, is frequently used to solve difficult challenges. However, machine learning (ML) techniques in this domain have ushered in a new era characterized by enhanced precision and adaptability. A survey [35] was conducted to assess the extent to which the deterministic maximum principle may be used in the context of production scheduling, supply chain management, and Industry 4.0 technologies.

2.4.3 Quality control and predictive maintenance

Quality control and predictive maintenance are critical for seamless operations. We discuss how ML is revolutionizing these aspects within ERP. In the enhancement of quality control and production optimization, authors of [36] proposed a platform that enables a visualizing framer work and maintains track of every alteration. IIoT sensors collect accurate data during the manufacturing process. ML algorithms examine these data to discover errors, identify quality disparities, and enhance production settings. Integration with ERP allows for instant quality control input, enabling for quick changes to meet product quality criteria. As a consequence, operations are more efficient, there is less waste, and customers are more satisfied.

Authors in [37] introduce topics in the realm of energy-efficient industrial IoT-based big data administration and analysis in cloud settings. ML algorithms incorporated into ERP systems evaluate IIoT data to intelligently automate repetitive chores and procedures. The proposed future aim was to include security and privacy concerns into this framework to achieve energy-efficient and safe cloud-based administration.

Consequently, IIoT sensors and devices are easily connected with ERP systems, allowing massive amounts of real-time data to be collected from multiple sources such as manufacturing equipment, supply chain components, and operational activities. ML algorithms process these data in real time, giving ERP modules rapid insights. This real-time connectivity enables ERP systems to make data-driven choices in real time, assuring maximum performance across all company functions.

2.5 Predictive maintenance and asset optimization and adaptive process automation

This part examines the manner in which machine learning (ML) techniques optimize assets and expedite maintenance operations. In order to accurately assess maintenance requirements, machine learning algorithms analyze data obtained from industrial Internet of Things (IIoT) linked machinery and equipment. Predictive maintenance models aim to optimize maintenance schedules, minimize downtime, and extend the lifetime of assets via the identification and analysis of trends and irregularities.

The use of this proactive technique ensures that enterprise resource planning (ERP) systems are able to effectively oversee and allocate resources, hence minimizing disruptions and enhancing production efficiency. Furthermore, adaptive process automation is the future of ERP. We examine how ML-driven automation is making ERP systems more agile and responsive, while ERP systems acquire the capacity to assess consumer behavior, preferences, and market trends by combining IIoT data with ML algorithms. In [38] paper a comprehensive literature review was conducted that focused on primary research articles pertaining to predictive maintenance, industry 4.0, and data science. Consequently, a range of essential procedures performed by a data scientist in the context of predictive maintenance were successfully identified. Yet, predictive analytics forecasts future patterns using past data and statistical algorithms, whereas prescriptive analytics suggests steps to improve outcomes. Predictive analytics in ERP may be used to estimate sales or demand, and prescriptive analytics can recommend appropriate pricing strategies or supply chain changes. Predictive analytics models reliably estimate demand in demand forecasting and consumer Insights domains, helping firms to align production and inventory levels with consumer demands. This connectivity guarantees that ERP systems can adapt to market demands in real time, improving customer happiness and boosting sales tactics.

In the same context, paper [42] investigated the effects of the IoT big data analytics paradigm (IoT BDA) on the installation and utilization of IoT-based technologies in healthcare services. Cloud ERP combined with IoT is a contemporary sector that promises better administration and customer service. By evaluating sensor data or photos, ML discovers flaws in real time. Predictive maintenance algorithms anticipate when equipment may break, saving downtime and maintenance costs.

2.5.1 Supply chain management and logistics

In the era of global supply chains, ML plays a pivotal role. We investigate how it's redefining supply chain management and logistics. By more correctly forecasting demand, ML approaches have changed inventory management. As a consequence, extra inventory expenses and inventory shortage are decreased. ML aids in talent recruiting, workforce planning, and employee retention in HR management. IIoT-enabled RFID, Radio-frequency identification, tags and sensors allow real-time visibility into inventory levels in the field of Intelligent Inventory Management. These data are processed by ML algorithms, which forecast demand patterns and optimize inventory level. The [43] growing field of prognostics, which leverages big data analytics, ML, and IoT, can enhance maintenance cycle and spare parts demand forecasting." The suggested maintenance, repair, and operation (MRO) categorization for all components and accompanying strategies was designed to address inventory management solutions from the standpoint of Industry 4.0 technologies.

ERP systems use ultimate insights to automate inventory replenishment, avoid stockouts, and reduce surplus inventory, resulting in considerable cost savings and enhanced supply chain efficiency. Supply chain management using predictive analytics [44] logistics predictive analytics employs both quantitative and qualitative methodologies to forecast past and future material flow and storage behavior, as well as associated costs and service levels. Predictive analytics may aid the supply chain managers obtain a competitive edge by forecasting consumer behaviors, minimizing risks, discovering new consumers, optimizing operations, and increasing customer happiness and loyalty in real time.

In [45] a scoping assessment of the relevant literature on supply chain resilience, SC management, and I4.0 presented and its findings highlighted and summarized the impact of I4.0 integration into SCs to SC resilience enhancement.

By forecasting demand, managing inventory, and dynamically routing shipments, machine learning optimizes supply chain operations. It adjusts to changes in real time, such as traffic conditions.

In [46], the authors examined and clarified the potential of artificial intelligence (AI) for supply chain and logistics management. Their conclusion was that AI technologies offer a predictive element to help decision-makers. However, in [47] the authors conducted an analytical review of the literature to determine which ML practices might assist the various stages of the "CRM" life cycle and extract current methods and applications for "CRM" life cycle management. From another perspective, paper [40] assessed major supply chain operations and investigated RFID technology acceptance and deployment to optimize supply chains. Other ML-ERP integration use cases from previous work are mentioned in Table 1.

3 Reviewing state-of-the-art techniques and advancements

This section critically reviews the latest developments in ML-driven ERP optimization, evaluating recent techniques and advancements. It offers valuable insights into the current trajectory of this field. Consequently, the state of the art in IIoT and ML integration within the ERP framework predicts an era of intelligent, data-driven decision-making. Businesses may achieve unprecedented levels of productivity, adaptability, and competitiveness in the contemporary digital world by harnessing the power of real-time data, predictive analytics, and adaptive automation.

Machine learning (ML) plays a pivotal role in enabling ERP systems to process and act on data as it flows in, ensuring that businesses can respond swiftly to changing conditions. This trend has had particularly impactful across industries, providing instant insights and actionable intelligence. The fusion of IoT and Edge Computing is gaining prominence. Edge computing, which processes data closer to the source, enhances ERP systems by enabling faster decision-making. Whether in manufacturing, logistics, or other sectors, this trend facilitates more agile and efficient operations.

The most recent studies, illustrated in Table 3, summarize the state-of-the-art use cases in the IIoT field. The table provides information on the ML algorithms used, along with a description of the pros and cons of each case.

However, the results of a first evaluation of distributed ledgers that could be used in the Internet of Things (IoT) in [51] showed that while they can process thousands of transactions per second, their performance usually does not scale to tens of devices because it falls off significantly as the number of devices increases. The study proposed that future research should concentrate on assessing distributed ledgers. Looking ahead, the future of ML-driven ERP optimization offers even greater advancements, such as more complex AI integration and larger applications.

According to studies [52], IoT technology has discovered more and more uses in a variety of contexts and aspects of daily life. It looked at a number of IoT protocols, technologies, and applications in day-to-day life. It also included a glossary of related words and the most recent, cutting-edge IoT architecture across a range of industries.

The authors of [53] set upward a framework for assessing the economic, social, technological, functional, and non-functional aspects of SMS performance. The development of SMS services has also advanced significantly, with the aim of enhancing the effectiveness of business requirements. Pairwise comparison is used to create a predictive analytics solution that examines SMS services and corporate requests.

4 Conclusion

This comprehensive investigation has unveiled a fertile landscape for integrating machine learning (ML) into enterprise resource planning (ERP) systems. Through an extensive exploration of literature and research, diverse applications, methodologies, challenges, and potential benefits have been uncovered, showcasing the multifaceted ways ML can optimize ERP functionality, efficiency, and decision-making. A summary of the key functionalities is provided in Table 2.

ML has emerged as a catalyst, significantly enhancing ERP performance across various domains. This enhancement is exemplified in areas such as inventory management, demand forecasting, production scheduling, quality control, predictive maintenance, adaptive process automation, and supply chain management. The transformative potential of ML in ERP is underscored by promising outcomes, including increased efficiency, reduced costs, and improved decision-making capabilities, as detailed in various use cases outlined in Table 1.

Moreover, our review delves into the state-of-the-art techniques, recent advancements, and emerging trends in this rapidly evolving field, offering valuable insights for both researchers and practitioners. The integration of Industrial Internet of Things (IIoT) and ML in the context of ERP has resulted in ground-breaking breakthroughs, as illustrated in Table 3. This review contributes to the knowledge base by describing the state-of-the-art improvements in ERP and showcasing the most advanced research works in this domain, encouraging a deeper understanding of the synergy between ML and ERP. It serves as an initial step toward novel advancements and applications within the realm of business technology.

In summary, the incorporation of Industrial Internet of Things (IIoT) and machine learning (ML) technology into ERP systems has brought about a significant transformation in conventional business operations. Enterprises now have the potential to enhance decision-making capabilities, optimize resource allocation, and improve customer satisfaction by effectively leveraging real-time data and predictive analytics.

5 Future work

This comprehensive review article scrutinizes the integration of Industrial Internet of Things (IIoT) and machine learning (ML) technologies in the context of enterprise resource planning (ERP) systems. In essence, our analysis illuminates the significant potential for the integration of machine learning (ML) into ERP systems, showcasing notable improvements in operational efficiency, cost-effectiveness, and decision-making across diverse ERP functions.

As we envision the future, promising prospects for further study and development emerge. Enhancing enterprise resource planning (ERP) systems with machine learning (ML) holds the promise of significant progress. Notably, there is a need for research in scalability studies focused on large organizations, along with an examination of the long-term impact of machine learning on company performance. These areas bear significant importance for future investigations.

By acknowledging and embracing these challenges and opportunities, both academics and practitioners possess the potential to drive the advancement of machine learning-driven ERP systems. This commitment ensures the sustained relevance and capacity for innovation within the dynamic realm of business technology. In summary, the incorporation of IIoT and ML into ERP systems has ushered in a significant transformation of traditional business operations. This study serves as a pivotal step toward novel advancements and applications within the realm of business technology. By acknowledging and embracing both opportunities and challenges, academics and practitioners have the potential to propel the advancement of ML-driven ERP systems, ensuring their sustained significance and capacity for innovation within the dynamic realm of business technology.

Abbreviations

ERP	Enterprise resource planning
IIoT	Industrial Internet of Things
IoT	Internet of Things
I 4.0	Industry four
ML	Machine learning
KPIs	Key performance indicators
SAP	System analysis program development
MRP	Material requirements planning
CRM	Customer relationship management
SRM	Supplier relationship management
GiMS	Graduation Intelligent Manufacturing System
MPC	Manufacturing planning and control
BDA	Big data analytics
PdM	Predictive maintenance
DT	Digital transformation
LSTM	Long short-term memory
SVM	Support vector machine
PPC	Production planning and control
RFID	Radio-frequency identification
MRO	Maintenance, repair, and operation
SC	Supply chain

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