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Highlights

Field Service Operations

Integrating AI and Machine Learning

Discovering Thoughts, Inventing Future



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SOFTWARE & DATA ENGINEERING

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CONTENTS OF THE ISSUE

- i. Copyright Notice
- ii. Editorial Board Members
- iii. Chief Author and Dean
- iv. Contents of the Issue

- 1. Integrating AI and Machine Learning in Project Management for Proactive Supply Chain Disruption Mitigation. ***1-11***
- 2. Trunk Stock Management: Challenges, Strategies, and Technical Solutions for Field Service Operations. ***13-20***
- 3. Market Basket Analysis using Machine Learning. ***21-26***
- 4. A Statistical Model for Predict Equity Price of the Apple Inc. company in the Information Technology Sector. ***27-31***

- v. Fellows
- vi. Auxiliary Memberships
- vii. Preferred Author Guidelines
- viii. Index



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Integrating AI and Machine Learning in Project Management for Proactive Supply Chain Disruption Mitigation

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Keywords: *artificial intelligence, machine learning, supply chain management, project management, risk mitigation, blockchain, predictive analytics, digital twins, smart contracts, supply chain resilience.*

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INTEGRATING AI AND MACHINE LEARNING IN PROJECT MANAGEMENT FOR PROACTIVE SUPPLY CHAIN DISRUPTION MITIGATION

Strictly as per the compliance and regulations of:



Integrating AI and Machine Learning in Project Management for Proactive Supply Chain Disruption Mitigation

Samuel Yaw Larbi^α, Emmanuel Opoku Manu^ο, Samuel Donatus^ρ, Dannel Kweku Assumang^ω,
John Paul Adimonyemma[¥] & Tunmise Suliat Oyekola[§]

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Additionally, the convergence of blockchain with AI and ML has introduced unprecedented transparency in supply chain operations. Blockchain-integrated AI enhances real-time tracking, while smart contracts automate compliance, ensuring greater accountability across global supply networks. However, despite these advancements, significant challenges persist. Issues such as data quality and bias in AI-based forecasting, high implementation costs, cybersecurity risks, ethical concerns, and resistance to AI adoption hinder widespread deployment.

Keywords: artificial intelligence, machine learning, supply chain management, project management, risk mitigation, blockchain, predictive analytics, digital twins, smart contracts, supply chain resilience.

1. INTRODUCTION

The global supply chain landscape has undergone significant transformations in recent years, with disruptions becoming more frequent, severe, and dynamic. Ordinarily, supply chain management (SCM)

focused on optimizing operational efficiency, reducing costs, and ensuring timely delivery of goods and services [1]. However, the increasing prevalence of geopolitical instability, natural disasters, trade restrictions, cyber threats, and pandemics have heightened vulnerabilities across global supply networks. The COVID-19 pandemic, for instance, caused unprecedented disruptions, exposing weaknesses in supply chain resilience and forcing organizations to rethink their risk management strategies [2]. Additionally, geopolitical conflicts such as the Russia-Ukraine war have disrupted critical supply chains, particularly in agriculture, energy, and semiconductor industries, leading to price volatility and product shortages [3].

With supply chains extending across multiple continents and involving various organizations, disruptions no longer remain isolated incidents but trigger ripple effects that impact entire industries and economies. These demand more proactive approaches that go beyond traditional risk assessment methods. Organizations must anticipate, identify, and mitigate risks in real-time, leveraging data-driven decision-making to ensure resilience, agility, and sustainability in their supply chain operations [4].

Project management plays a critical role in ensuring supply chain resilience by providing structured methodologies for managing uncertainties, risks, and disruptions [5]. Traditionally, supply chain managers rely on linear, sequential models that emphasize stability and efficiency [6]. However, in a volatile, uncertain, complex, and ambiguous (VUCA) world, these models often fail to address the dynamic nature of modern supply chains [7].

Integrating project management principles into SCM allows organizations to adopt a proactive approach by implementing agile methodologies, risk-based planning, and real-time monitoring of supply chain performance [5]. Project-based approaches enable firms to rapidly respond to unforeseen events, optimize resource allocation, and enhance collaboration among stakeholders. Agile methodologies such as Scrum and Kanban allow supply chain managers to iterate and refine processes continuously, while

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traditional project management techniques, such as Critical Path Method (CPM) and Work Breakdown Structures (WBS), help streamline complex supply chain projects [8,9]. Despite these advantages, current SCM practices still operate in siloed environments, with project management and supply chain operations being treated as distinct disciplines.

With the rapid advancements in Artificial Intelligence (AI) and Machine Learning (ML), organizations are now turning to data-driven approaches to mitigate supply chain risks and optimize operational performance. AI-powered solutions can predict disruptions, automate decision-making, and enhance real-time visibility, making supply chains more adaptive and resilient [10]. Although, while AI and ML provide unparalleled capabilities in supply chain risk management, their integration requires strategic planning, robust data infrastructure, and cross-functional collaboration.

Given the complexity of modern supply chains, combining AI/ML with project management methodologies presents a promising solution for proactive disruption mitigation. The structured approach of project management, when enhanced with AI-driven analytics and automation, can enhance risk prediction and prevention by integrating AI models into supply chain risk registers, improve real-time decision-making through leveraging AI-powered capability in project execution, optimize resource allocation and cost efficiency through ML-based supply chain simulations, and foster agile supply chain planning that adapts dynamically to market uncertainties [11,12].

Organizations that successfully integrate AI/ML with project management can build highly adaptive, self-learning supply chain ecosystems, reducing the impact of disruptions while driving cost savings and operational efficiency.

II. LITERATURE REVIEW

Supply chain disruptions refer to sudden or prolonged interruptions in the flow of goods, services, or information within a supply network, often leading to significant operational and financial repercussions [13]. Historically, major supply chain disruptions have shaped risk management strategies across industries. The COVID-19 pandemic was one of the most profound disruptions in recent history, exposing vulnerabilities in manufacturing, logistics, and inventory management. Border closures, labour shortages, and fluctuating demand created significant bottlenecks, delaying shipments worldwide [2]. Similarly, geopolitical tensions, such as the Russia-Ukraine conflict, have disrupted the supply of critical raw materials like wheat, crude oil, and semiconductor components [14]. Beyond these macroeconomic shocks, natural disasters have also played a major role in destabilizing supply chains. The

2011 Tōhoku earthquake and tsunami in Japan, for example, severely affected global electronics and automotive production, as the country was a hub for semiconductor manufacturing [15]. The 2011 Thailand floods further intensified disruptions, impacting companies reliant on hard disk drive manufacturing [16]. Cybersecurity threats, another growing risk, have also emerged as a critical concern. Ransomware attacks targeting shipping giants, such as the 2017 cyberattack on Maersk, resulted in financial losses exceeding \$300 million and caused widespread delays in international freight operations [17].

Conventional supply chain risk management has largely relied on reactive strategies, often failing to anticipate and mitigate severe disruptions. Companies have long relied on maintaining inventory buffers, diversifying suppliers, and enforcing strict contractual agreements to reduce dependency on single sources [18]. Common risk assessment frameworks, such as Analytical Network Process (ANP) and Analytical Hierarchy Process (AHP), tend to be static, making them inadequate for addressing real-time volatility in global supply networks [19]. As supply chain risks grow more unpredictable, the need for dynamic, AI-driven predictive models has become increasingly evident.

III. AI AND ML IMPLEMENTATION IN PROJECT MANAGEMENT FOR SUPPLY CHAIN DISRUPTION MITIGATION

a) AI-Powered Risk Identification and Forecasting

The unpredictability nature of modern supply chains necessitates more sophisticated approaches to risk identification and forecasting. Traditional risk assessment models, which rely on historical data and rule-based decision-making, often struggle to capture the dynamic nature of global trade disruptions. Artificial Intelligence (AI) offers a paradigm shift by enabling real-time analysis and predictive insights, allowing companies to detect early signs of disruptions and implement proactive mitigation strategies [12].

One of the most transformative applications of AI in risk identification is its ability to analyse vast and diverse datasets to uncover hidden vulnerabilities within the supply chain. AI-powered predictive analytics leverage machine learning algorithms to detect anomalies, assess supplier reliability, and anticipate fluctuations in demand or supply constraints [20]. Big data analytics, particularly when integrated with AI, enhances predictive capabilities by processing real-time market signals, geopolitical developments, and environmental factors to assess potential risks. For instance, AI models trained on trade data and transportation trends can anticipate port congestion or shipping delays, enabling companies to reroute shipments before bottlenecks materialize [21].

AI-driven demand forecasting is a crucial tool for preventing stock outs and overstocking, two common challenges in supply chain management [22]. Conventional forecasting methods, often reliant on static statistical models, fail to account for sudden shifts in consumer behaviour or external disruptions such as pandemics or geopolitical tensions. AI-enhanced forecasting systems continuously learn from new data sources, including customer purchasing trends, macroeconomic indicators, and even social media sentiment analysis. Companies such as Amazon and Walmart have successfully implemented AI-based forecasting models that dynamically adjust inventory levels based on real-time demand fluctuations [23]. This not only optimizes inventory management but also minimizes financial losses from excess stock or lost sales due to shortages.

Despite the advantages of AI in risk identification, there are challenges that remain in its

implementation. Data quality and accessibility pose significant hurdles, as AI systems rely on large, high-quality datasets to generate accurate predictions. Many organizations face issues with fragmented data storage, siloed operations, and inconsistent data governance, which can compromise the effectiveness of AI models [24, 25]. Additionally, biases inherent in historical data can lead to inaccurate forecasts, reinforcing existing vulnerabilities rather than mitigating them [26].

Moreover, the integration of AI into supply chain risk management requires a fundamental shift in organizational culture and decision-making processes. Many firms still rely on manual or experience-based risk assessments, and transitioning to an AI-driven approach demands investment in digital infrastructure and workforce upskilling [27]. AI models must be continuously refined and adapted to evolving risk landscapes to ensure their reliability.



Fig. 3.1: AI-Powered Risk Identification and Forecasting

IV. MACHINE LEARNING MODELS FOR PROACTIVE DISRUPTION MITIGATION

Machine learning (ML) has emerged as a critical tool in proactive disruption mitigation, offering the ability to analyse complex datasets, identify emerging risks, and optimize supply chain responses in real-time. Unlike traditional risk management approaches that focus on reactive strategies, ML-driven solutions enable predictive and adaptive decision-making, reducing the impact of disruptions before they escalate into crises [22].

Supervised and unsupervised learning models play a crucial role in supply chain optimization. Supervised learning algorithms, trained on labelled datasets, help predict supplier performance, transportation delays, and demand fluctuations with high accuracy [28]. These models analyse historical data, detecting recurring patterns and providing solutions into potential disruptions. For example, predictive analytics platforms powered by supervised learning have been employed to assess supplier risk by analysing financial stability, geopolitical factors, and

past delivery performance [29]. Companies leveraging such models can proactively diversify their supplier base or renegotiate contracts to ensure continuity in operations.

On the other hand, unsupervised learning models, which operate without predefined labels, excel in anomaly detection within logistics, inventory management, and transportation networks [30]. These models identify deviations from expected patterns, flagging potential disruptions that may not be evident through conventional analysis. In logistics, for instance, unsupervised learning is used to detect irregularities in shipment movements, such as unexpected delays or route deviations, which could indicate potential supply chain risks such as theft, fraud, or unforeseen logistical constraints [31].

ML based anomaly detection also enhances the security and resilience of supply chain operations. Algorithms trained on vast datasets can identify cyber threats targeting logistics infrastructure, supplier networks, or digital transaction platforms [32]. With increasing cyber vulnerabilities in global supply chains, MLdriven security measures are essential in preventing data breaches and ensuring compliance with regulatory frameworks.

The application of predictive analytics in supplier risk management further highlights the strategic value of ML in disruption mitigation. Geopolitical developments, and environmental factors, ML models provide dynamic risk assessments through the analyses of real-time data on supplier operations, allowing businesses to make informed sourcing decisions. For example, during the COVID-19 pandemic, companies utilizing ML-driven supplier risk management systems were able to anticipate factory shutdowns in affected regions and shift procurement strategies accordingly [33]. This level of foresight was critical in maintaining production continuity and minimizing financial losses.

However, the implementation of ML-based proactive disruption mitigation strategies is not without challenges. One of the primary barriers is the need for highquality, integrated data across the supply chain ecosystem. Many organizations operate in siloed environments where data-sharing limitations hinder the effectiveness of ML models. Additionally, the computational complexity of ML algorithms necessitates substantial investments in cloud computing infrastructure and skilled data science expertise.

Moreover, reliance on ML for decision-making requires careful monitoring to ensure model accuracy and ethical considerations. The presence of bias in training datasets can lead to skewed risk assessments, disproportionately affecting certain suppliers or regions [34]. Transparency in ML driven decision-making processes is essential to maintain trust among stakeholders and avoid unintended consequences.

Nevertheless, the integration of ML into supply chain risk management offers significant advantages in enhancing resilience and responsiveness. As technological advancements continue to refine ML capabilities, businesses that embrace these tools will be better positioned to navigate disruptions and maintain competitive agility in an increasingly volatile global market.

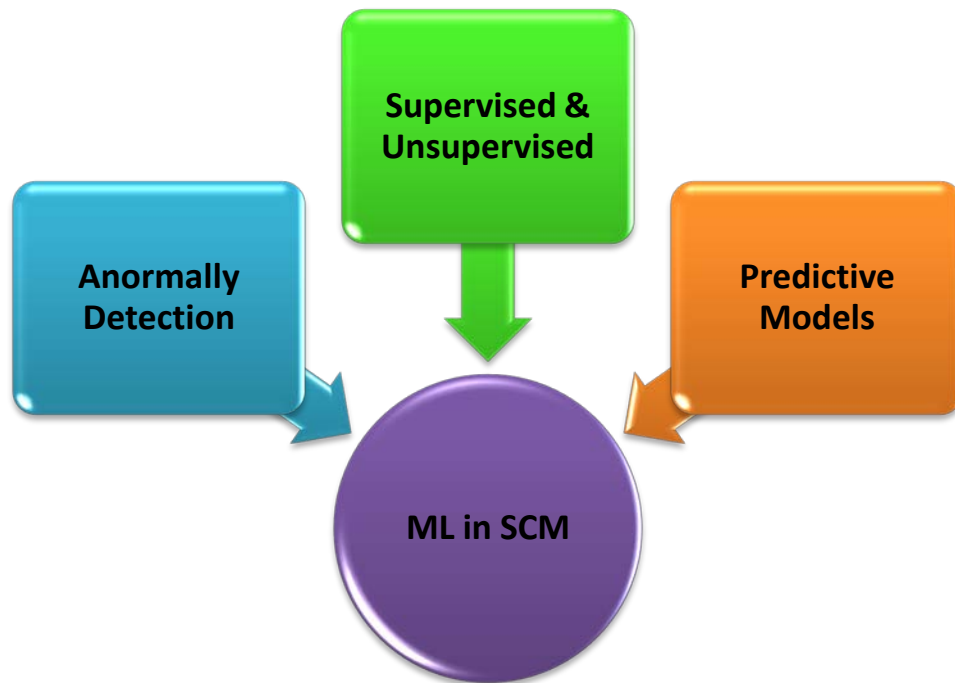


Fig. 3.2: Machine Learning Model for Proactive Model Disruption Mitigation

V. AI IN DECISION-MAKING AND REAL-TIME SUPPLY CHAIN ADAPTATION

AI driven tools such as scenario planning, simulation, automation, chatbots, and digital twins have become pivotal in enhancing operational efficiency and resilience.

AI-driven scenario planning and simulation have become indispensable in modern project management, particularly within supply chains through analysing vast datasets, AI can model various scenarios, predict potential disruptions, and assess their impacts on the supply chain. This enables managers to develop contingency plans and optimize decision-making processes [12].

AI-powered platforms can simulate the effects of geopolitical events, natural disasters, or market fluctuations on supply chains [35]. These simulations allow project managers to visualize potential outcomes and devise strategies to mitigate risks. The ability to anticipate and prepare for various scenarios enhances the agility and resilience of supply chains, ensuring continuity in operations despite uncertainties.

In addition, AI-driven simulations facilitate resource optimization by identifying bottlenecks and inefficiencies within the supply chain. It enables project managers to allocate resources more effectively, reduce operational costs, and improve overall performance by modelling different operational strategies. This data-driven approach replaces traditional trial and error methods, leading to more informed and efficient decision-making.

Automation, powered by AI, has transformed supply chain logistics by streamlining operations and reducing human intervention in routine tasks. AI algorithms can optimize routing, manage inventory levels, and forecast demand with high accuracy, leading to cost savings and improved service levels. For example, AI-driven automation in warehouses includes the use of robotics for sorting and packing, which accelerates order fulfilment and reduces errors. Companies like Amazon have invested heavily in robotics and AI to enhance their logistics operations. Amazon's advanced fulfillment centres utilize AI-powered robots to move goods efficiently, resulting in significant cost reductions and faster delivery times [36]. Also, AI-powered automation extends to transportation management. AI systems analyse traffic patterns, weather conditions, and delivery schedules to determine the most efficient routes for shipments [37, 38]. This optimization reduces fuel consumption, lowers transportation costs, and ensures timely deliveries, thereby enhancing customer satisfaction. Given an example, using AI Chatbots and Digital Twins in Predictive Supply Chain Management. These two represent innovative applications of AI in predictive supply chain management.

AI chatbots serve as virtual assistants, facilitating real-time communication between various stakeholders in the supply chain. They can handle inquiries, provide updates on shipment statuses, and assist in coordinating tasks among suppliers, manufacturers, and distributors [39]. This real-time

interaction enhances transparency and responsiveness within the supply chain.

Conversely, digital twins are virtual reproductions of actual assets, processes, or entire supply chain networks. Digital twins, which combine real-time data with AI algorithms, enable continuous monitoring and modeling of supply chain operations. This technology enables businesses to anticipate potential disruptions, assess the impact of changes, and enhance processes before they are implemented in the real world. For example, in the manufacturing industry, digital twins can mimic production line changes to assess their impact on output and quality. This feature enables proactive decision-making,

resulting in less downtime and increased operational efficiency. Similarly, in logistics, digital twins can simulate transportation networks to determine the best routing options, ultimately boosting delivery performance.

The integration of AI into decision-making and real-time supply chain adaptation offers substantial benefits, including enhanced predictive capabilities, operational efficiency, and resilience. As AI technologies continue to evolve, their applications in supply chain management are poised to become even more transformative, enabling businesses to navigate complexities and uncertainties with greater agility.

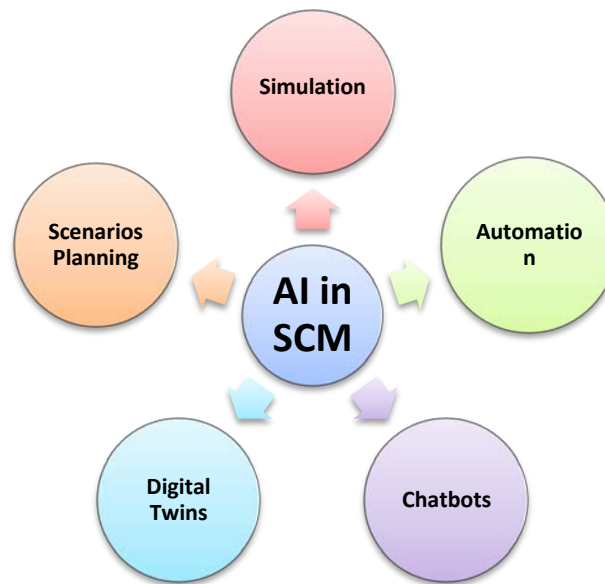


Fig 3.3: AI in Decision-Making and Real-Time Supply Chain Adaptation

VI. BLOCKCHAIN, AI, AND ML FOR SUPPLY CHAIN TRANSPARENCY

The convergence of Blockchain technology, Artificial Intelligence (AI), and Machine Learning (ML) enhances real-time tracking, automates compliance through smart contracts, and offers innovative solutions, particularly in industries like pharmaceuticals.

Blockchain provides a decentralized and immutable ledger system, ensuring that every transaction within the supply chain is recorded transparently and securely [40]. When combined with AI, this system becomes even more powerful. AI algorithms can analyse the vast amounts of data stored on a blockchain to identify patterns, predict potential disruptions, and optimize operations [41]. For example, in the food industry, integrating blockchain with AI allows companies to track products from farm to table. This integration ensures that data regarding the origin, handling, and transportation of food items is accurate and readily accessible. AI can analyse this data to

predict shelf life, monitor quality, and even suggest optimal delivery routes, thereby reducing waste and ensuring product safety.

Smart contracts are self-executing contracts with the terms directly embedded in code, operating on blockchain networks. They automatically enforce and execute agreements when predefined conditions are met, reducing the need for intermediaries and expediting processes [42]. In global supply chains, smart contracts facilitate automated compliance by ensuring that all parties adhere to regulatory requirements and contractual obligations. For instance, in the automotive industry, smart contracts can automatically verify that components meet safety standards before they are assembled into vehicles [43, 44]. If a component fails to meet the required specifications, the smart contract can trigger actions such as halting production or notifying suppliers, thereby preventing potential safety issues. Additionally, smart contracts streamline financial transactions by

automating payments upon the fulfillment of contractual terms [45].

This automation reduces delays, minimizes errors, and enhances trust among parties.

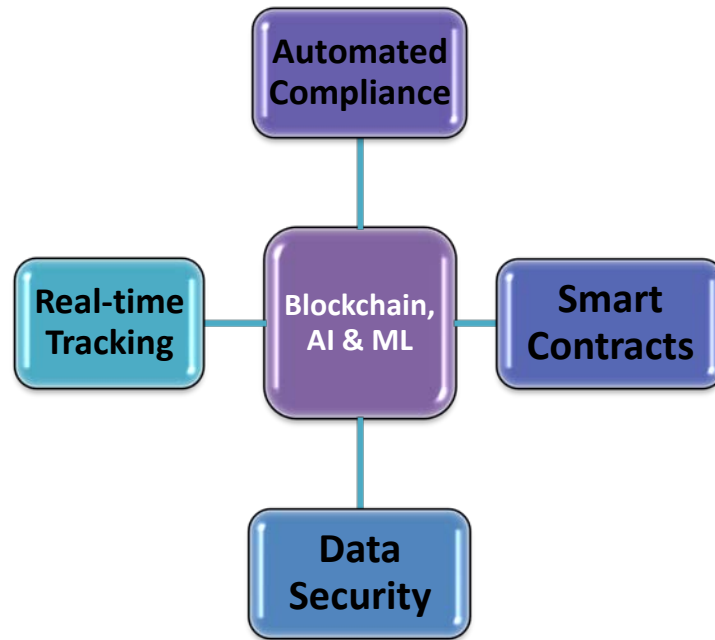


Fig 3.4: Blockchain, AI, and ML for Supply Chain Transparency

VII. CHALLENGES AND LIMITATIONS OF AI/ML IN SUPPLY CHAIN PROJECT MANAGEMENT

The integration of artificial intelligence (AI) and machine learning (ML) in supply chain management enhances efficiency and resilience. However, several critical challenges and limitations hinder their full potential. These challenges include data quality and bias, high implementation costs, ethical and legal concerns, cybersecurity threats, and resistance to AI adoption. Addressing these issues is essential for organizations seeking to optimize AI-driven supply chain solutions.

a) Data Quality and Bias Issues in AI-based Forecasting

One of the most pressing challenges in AI and ML adoption is ensuring high-quality, unbiased data. AI models rely on large datasets to make accurate predictions, but these datasets often contain inconsistencies, missing values, or biased information, which can result in flawed decision-making. The “garbage in, garbage out” principle applies here: poor-quality data leads to unreliable AI predictions.

Furthermore, AI models trained on historical data inherit past biases. For example, if past procurement decisions favoured certain suppliers due to non-performance-related factors, AI may reinforce these biases rather than promoting optimal decision-making.

Addressing bias requires continuous data auditing, diverse training datasets, and the application of fairness-aware ML techniques.

b) High Implementation Costs and Technological Barriers

Despite the promise of AI and ML, the high costs associated with their implementation pose significant barriers, particularly for small and medium enterprises (SMEs). The initial investment in AI infrastructure, including computing power, data integration, and skilled personnel, is substantial. Many organizations also face difficulties in integrating AI with legacy supply chain systems, requiring costly system overhauls and custom solutions to ensure interoperability.

Moreover, AI-driven supply chain management demands ongoing system maintenance, retraining of ML models, and cybersecurity investments. Companies must weigh the long-term benefits against the short-term financial burden, often leading to delayed AI adoption in supply chain project management.

c) Ethical and Legal Concerns in AI-Driven Decision-Making

AI decision-making in supply chains raises ethical and legal concerns, particularly regarding transparency, accountability, and compliance. The use of AI for supplier selection, demand forecasting, and risk mitigation can lead to opaque decision-making

processes, making it difficult to attribute responsibility when errors occur.

Additionally, AI-driven automation in procurement and contract management raises questions about legal compliance. Smart contracts, which execute transactions autonomously, may lack the flexibility to accommodate unforeseen contractual disputes. Regulatory bodies are still catching up with AI advancements, and the legal framework for AI-driven supply chains remains underdeveloped.

d) *Cybersecurity Threats and AI Vulnerabilities in Supply Chain Management*

AI and ML provide new cybersecurity dangers to supply networks. Artificial intelligence systems are vulnerable to adversarial attacks, in which malicious users modify input data to trick models into generating inaccurate predictions. For example, attackers could compromise AI-powered logistics systems by feeding false data, disrupting shipment scheduling and inventory management.

Furthermore, AI models require access to vast amounts of sensitive supply chain data, raising concerns about data breaches and privacy violations. Companies that fail to implement robust security measures risk exposing trade secrets, financial records, and supplier information to cyber threats.

To mitigate cybersecurity risks, organizations must invest in AI-specific security solutions, such as anomaly detection systems that identify unusual patterns indicative of cyberattacks. Additionally, AI governance frameworks should enforce strict access controls and encryption protocols to protect critical supply chain data.

e) *Resistance to AI Adoption by Traditional Supply Chain Managers*

A significant barrier to AI adoption in supply chain project management is resistance from traditional supply chain managers. Many professionals accustomed to conventional supply chain methodologies view AI as a disruptive force that threatens job security and undermines human expertise.

Organizational resistance often stems from a lack of AI literacy and training. Without adequate knowledge of AI capabilities and limitations, decision-makers may be sceptical of AI-driven recommendations. Additionally, concerns about AI replacing human judgment in critical supply chain decisions contribute to reluctance in embracing AI solutions.

To overcome this challenge, organizations must prioritize change management strategies, offering comprehensive AI training programs and fostering a culture of collaboration between AI-driven insights and human expertise. Encouraging supply chain managers to engage in AI-assisted decision-making rather than viewing AI as a replacement can facilitate smoother adoption.

VIII. CONCLUSION

The integration of Artificial Intelligence (AI) and Machine Learning (ML) in supply chain project management represents a transformative shift in how organizations approach risk mitigation, decision-making, and operational efficiency. This paper has critically examined the role of AI and ML in supply chain disruption mitigation, highlighting their potential to enhance forecasting accuracy, optimize logistics, and improve transparency.

The study emphasises that AI-powered risk identification and forecasting have revolutionized supply chain resilience. AI's ability to analyse vast datasets in real-time allows for early detection of potential disruptions, enhancing proactive decision-making. Machine learning models, both supervised and unsupervised, enable predictive analytics in supplier risk management and anomaly detection, offering organizations a strategic advantage in mitigating risks before they escalate.

AI-driven decision-making and real-time supply chain adaptation have further enhanced agility and responsiveness in project management. Technologies such as digital twins and AI-powered scenario planning provide organizations with the ability to simulate potential disruptions and optimize responses. Automation in logistics, driven by AI, has significantly improved supply chain efficiency, reducing operational costs while ensuring optimal resource allocation.

Additionally, the convergence of blockchain with AI and ML has introduced new levels of transparency and security in supply chain operations. Blockchain-enabled smart contracts facilitate automated compliance, while AI enhances real-time tracking and fraud detection. Case studies, particularly in the pharmaceutical industry, illustrate how AI-blockchain integration ensures regulatory adherence and prevents counterfeit products from entering the market.

Despite these advancements, this paper also highlights the limitations and challenges of AI in supply chain management. Issues such as poor data quality, ethical concerns surrounding AI-driven decision-making, cybersecurity vulnerabilities, and resistance from traditional supply chain managers pose significant barriers to adoption. Organizations must address these concerns through robust data governance, ethical AI frameworks, and targeted training programs to bridge the gap between AI potential and practical implementation.

Furthermore, the discussion on blockchain and AI integration give the potential for decentralized, tamper-proof records to revolutionize supply chain tracking and compliance. This paper also brings attention to the pressing need for ethical AI frameworks and cybersecurity protocols to mitigate the risks associated with AI deployment in supply chains.

For AI to fulfil its potential in supply chain management, businesses must adopt a balanced approach that combines technological advancements with human expertise. AI should be viewed as an enabler rather than a replacement for human decision-making. Companies must also invest in ethical AI frameworks to ensure fair and transparent decision-making processes while addressing regulatory compliance concerns.

IX. RECOMMENDATIONS

Future research should focus on refining AI models to address inherent biases in data-driven decision-making. The development of more robust AI frameworks capable of operating with incomplete or unstructured data will be critical for enhancing supply chain resilience. Additionally, more empirical studies are needed to assess the long-term impact of AI implementation on supply chain efficiency, sustainability, and profitability.

Further exploration of AI and blockchain integration will be essential in ensuring secure, transparent, and efficient supply chains. Future research should investigate scalable AI-blockchain solutions tailored for different industries, assessing their viability in real-world applications.

Lastly, research should explore the human-AI collaboration model in supply chain management. Understanding how AI can complement rather than replace human expertise will be vital in driving adoption and maximizing the benefits of AI-driven supply chains.

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Trunk Stock Management: Challenges, Strategies, and Technical Solutions for Field Service Operations

By Jeyaganesh Viswanathan

Abstract- This paper analyzes the challenges of trunk stock management for field service operations and proposes improvement solutions. Trunk stock, the inventory carried by field service technicians, poses unique management challenges due to its mobile nature and frequent transactions. Manual reporting methods can lead to errors and delays, resulting in stockouts, overstocking, or inaccurate costing. The research proposes integrating mobile inventory scanning with cloud-based software to track inventory in real-time or near real-time. Additionally, the study explores the potential of the consignment process in SAP ERP for managing trunk stock. A field study and SAP ERP pilot are outlined to test the proposed solutions. The findings aim to provide insights for service organizations to enhance trunk stock management practices, reduce errors, and improve operational efficiency. The paper concludes by discussing the implications and suggesting areas for further research, including the application of emerging technologies like IoT sensors and blockchain.

Keywords: *trunk stock management, field service, inventory tracking, real-time reporting, SAP ERP, consignment process, mobile scanning, cloud-based software.*

GJCST-C Classification: LCC Code: HD38.5



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I. INTRODUCTION

Effective management of trunk stock inventory is critical for field service operations to maintain accuracy with system-reported stock levels and costs. Trunk stock, a collection of commonly used parts and materials, enables field service technicians to complete jobs efficiently without delays in procuring needed items [1]. However, managing this mobile inventory poses significant challenges in maintaining accurate system records of stock levels and costs. Manual reporting by technicians can lead to errors, and stockroom personnel may not update the system in a timely manner, resulting in stockouts, overstocking, or inaccurate costing [2].

Several studies have addressed inventory management in field service, but trunk stock presents unique challenges due to its mobile nature and frequent transactions [3]. Manual methods, such as technicians reporting consumption via paperwork, can lead to errors and delays in updating system inventory [4]. Automated identification and data capture (AIDC) technologies, like barcode scanning or RFID, have been proposed to

improve accuracy and efficiency [5]. However, implementing such technologies for trunk stock can be complex due to the variety of items, limited access to scanning infrastructure in the field, and costs of tagging all inventory [6].

This paper aims to identify existing problems in trunk stock management and propose solutions for improvement, with a focus on real-time or near real-time inventory tracking and reporting. The research will examine the process of tracking inventory when field technicians carry stock for service visits, including the discussion on reporting consumed stock to adjust system inventory accurately. The study will explore the potential of managing trunk stock through the consignment process in SAP ERP. The findings of this research can provide insights for service organizations to enhance their trunk stock management practices, reduce errors, and improve operational efficiency.

The paper will be organized as follows: The related work section will review existing literature on trunk stock management, highlighting gaps in current practices. The theory/calculation section will discuss key concepts and formulas relevant to trunk stock management. The design section will propose a solution involving mobile inventory scanning and cloud-based software, as well as the use of the SAP ERP consignment process. The experimental method section will outline a field study and SAP ERP pilot to test the proposed solutions. The results and discussion section will analyze the findings from the field study and pilot. The analysis section will detail the methods for analyzing the data collected. The figures and tables section will include visual aids to illustrate the concepts and findings. The conclusion and future scope section will summarize the results, discuss implications, and suggest areas for further research.

II. RELATED WORK

Several studies have addressed inventory management in field service, highlighting the unique challenges of managing trunk stock due to its mobile nature and frequent transactions [7].

Boone *et al.* identified critical challenges of inventory management in service parts supply, including

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the need for timely return of unserviceable parts by field service providers [8].

- *Objectives*
 - To identify critical challenges in managing front-end and back-end inventory in service parts supply chains.
 - To understand the impact of inventory decisions on service levels and costs.
- *Problem Statement:* Managing service parts inventory is complex due to the need to balance front-end (field service) and back-end (central warehouse) inventory. Challenges include the timely return of unserviceable parts, multi-echelon inventory optimization, and the trade-off between service levels and inventory costs. Addressing these challenges is crucial for service organizations to improve their parts supply chain management and overall service operations.

Weathers discussed the trade-offs between field engineer staffing budgets and spare parts inventory budgets in field service support [9]. Real-time inventory tracking has been proposed to improve accuracy and efficiency.

- *Objectives*
 - To examine the trade-offs between field engineer staffing budgets and spare parts inventory budgets in field service support.
 - To understand how these trade-offs impact service performance and costs.
- *Problem Statement:* Field service organizations face trade-offs between investing in field engineer staffing versus spare parts inventory. Increasing engineer staffing can improve service responsiveness but at higher labor costs. Conversely, holding more spare parts inventory can ensure service completion but at higher inventory costs. Balancing these trade-offs is critical for service organizations to optimize their field service support operations and improve customer service levels while controlling costs.

Mishra and Mohapatro presented an IoT cloud architecture for real-time tracking of stock-keeping units using passive RFID tags [10].

- *Objectives*
 - To present an IoT cloud architecture for real-time tracking of stock-keeping units using passive RFID tags.
 - To demonstrate the potential of IoT and cloud computing for improving inventory management.
- *Problem Statement:* Traditional inventory management methods often lack real-time visibility into stock levels and locations. The use of IoT technologies like RFID tags and cloud computing

can enable real-time inventory tracking and improve accuracy, reducing stockouts and overstocking. However, implementing such solutions requires integrating IoT devices with cloud-based systems and addressing technical challenges like data analytics and security. Leveraging IoT and cloud computing is crucial for organizations to transform their inventory management practices and gain a competitive advantage.

Musana et al. developed a real-time inventory tracking model to prevent delays in restocking airline products [11].

- *Objectives*
 - To develop a real-time inventory tracking model to prevent delays in restocking airline products.
 - To demonstrate the application of real-time inventory tracking in a specific industry context.
- *Problem Statement:* In industries like telecommunications, delays in restocking airline products can lead to lost sales and customer dissatisfaction. Real-time inventory tracking can help prevent stockouts by triggering replenishment orders when inventory levels reach certain thresholds. Implementing such systems requires integrating real-time data feeds with inventory management software and defining appropriate reorder points and quantities. Enabling real-time inventory tracking is critical for organizations to improve their stock replenishment processes and maintain high service levels.

Yao and Carlson discussed the impact of real-time data communication on inventory management, including the use of barcoding and scanning [12].

- *Objectives*
 - To discuss the impact of real-time data communication on inventory management.
 - To examine the role of technologies like barcoding and scanning in enabling real-time inventory tracking.
- *Problem Statement:* Traditional inventory management often relies on periodic counting and manual updates, leading to inaccuracies and inefficiencies. Real-time data communication enabled by technologies like barcoding, scanning, and RFID can improve inventory accuracy and reduce stockouts and overstocking. However, implementing real-time inventory systems requires integrating data capture technologies with inventory management software and addressing challenges like data synchronization and system integration. Leveraging real-time data communication is crucial for organizations to transform their inventory management practices and improve operational efficiency.

Faur and Bungau highlighted the consignment stock program as an excellent option for leagile supply chains, with clearly defined responsibilities and robust ERP software like SAP [13].

- *Objectives*

- To highlight the consignment stock program as an option for leagile supply chains.
- To discuss the benefits of consignment management, including clearly defined responsibilities and robust ERP software like SAP.

- *Problem Statement:* Managing inventory in leagile supply chains, which combine elements of lean and agile approaches, requires flexible and responsive solutions. Consignment stock programs, where the supplier retains ownership of inventory until it is consumed, can offer benefits like reduced inventory risk and improved cash flow for buyers. Implementing consignment programs requires clearly defining responsibilities, setting up appropriate processes, and leveraging robust ERP systems like SAP. Enabling consignment management is critical for organizations to optimize their inventory management practices in leagile supply chains.

Agrawal provided process steps and configuration details for customizing materials management processes in SAP ERP [14]. Mobile scanning and cloud-based software have been proposed to enhance inventory management.

- *Objectives*

- To provide process steps and configuration details for customizing materials management processes in SAP ERP.
- To demonstrate how SAP ERP can be tailored to support specific inventory management requirements.

- *Problem Statement:* ERP systems like SAP offer robust functionality for managing inventory, but require configuration to support specific business processes and requirements. Customizing materials management processes in SAP ERP involves setting up organizational structures, defining material master data, configuring valuation and inventory management processes, and implementing user roles and authorizations. Properly configuring SAP ERP is critical for organizations to leverage its full potential and improve their inventory management practices. Addressing the complexity of SAP configuration and ensuring user adoption are key challenges in implementing SAP ERP for inventory management.

Kar developed a mobile-based inventory management system using QR codes [15].

- *Objectives*

- To develop a mobile-based inventory management system using QR codes.
- To demonstrate the potential of mobile technologies for improving inventory management.

- *Problem Statement:* Traditional inventory management often involves manual counting and paper-based reporting, leading to errors and inefficiencies. Mobile technologies, like smartphones and tablets, can enable real-time inventory tracking and update of system records. The use of QR codes can simplify item identification and data capture. Implementing mobile inventory systems requires developing user-friendly interfaces, integrating with back-end systems, and addressing technical challenges like connectivity and data security. Leveraging mobile technologies is crucial for organizations to improve their inventory management practices and increase technician productivity.

Olanrewaju et al. presented a cloud-based inventory system to effectively manage under and overstock hazards [16].

- *Objectives*

- To present a cloud-based inventory system for effectively managing under and overstock hazards.
- To demonstrate the application of cloud computing for real-time inventory tracking and automated alerts.

- *Problem Statement:* Inventory management systems often lack real-time visibility into stock levels, leading to stockouts or overstocking. Cloud-based inventory systems can provide real-time tracking and automated alerts when inventory levels reach certain thresholds. Implementing cloud-based systems requires selecting appropriate software, integrating with existing systems, and ensuring data security and reliability. Leveraging cloud computing is critical for organizations to transform their inventory management practices and improve operational efficiency.

Adegbaaju and Odun-Ayo discussed the development of a cloud-based inventory management system [17].

- *Objectives*

- To discuss the development of a cloud-based inventory management system for SMEs.
- To highlight the benefits of cloud-based systems, including cost-effectiveness and scalability.

- *Problem Statement:* Small and medium-sized enterprises (SMEs) often have limited resources for

inventory management systems. Cloud-based inventory systems can offer cost-effective and scalable solutions, eliminating the need for upfront software and hardware investments. Implementing cloud-based systems requires selecting appropriate vendors, ensuring data security and reliability, and providing user training. Leveraging cloud computing is critical for SMEs to improve their inventory management practices and compete effectively with larger organizations. Addressing the challenges of cloud adoption and ensuring vendor support are key issues in implementing cloud-based inventory systems for SMEs.

These studies highlight the need for integrated solutions that leverage mobile scanning, cloud-based software, and ERP systems like SAP to

effectively manage trunk stock in field service operations.

III. THEORY/CALCULATION

a) Theory

Effective trunk stock management requires understanding key concepts. One crucial aspect is inventory accuracy, which is vital for preventing stockouts and overstocking [18]. Another important concept is the economic order quantity (EOQ), which minimizes total inventory costs [19]. In addition, lead time, which is the time between placing an order and receiving the inventory, impacts stock levels [20]. By understanding inventory accuracy, EOQ, and lead time, you can develop practical strategies to improve your trunk stock management [21].

b) Calculation

Inventory accuracy can be measured using the inventory record accuracy (IRA) formula:

$$\text{IRA} = (\text{Total number of items} - \text{Total number of stock record errors}) / \text{Total number of items} * 100$$

The EOQ formula is:

$$\text{EOQ} = \sqrt{2 \text{ Annual demand Ordering cost} / \text{Holding cost}}$$

By calculating the EOQ, organizations can determine the optimal order quantity to reduce inventory costs.

c) Design

The study employed a two-phase design to test the proposed solutions for trunk stock management. Phase 1 involved implementing the mobile scanning and cloud-based software solution with a sample of technicians for 3 months. The solution was configured to scan items when issuing from or returning to the trunk stock, update system records in real-time, and set alerts for low stock levels to trigger replenishment [22]. The technicians were trained on the use of the mobile scanning solution and support was provided throughout the implementation period.

Phase 2 piloted the SAP ERP consignment process with a few items to assess the process flow and system configuration for receiving stock, issuing stock to technicians, and reporting consumption. The SAP ERP system was customized according to the consignment process requirements and user acceptance testing was conducted prior to the pilot [23].

This figure illustrates the technical architecture of managing trunk stock in an ERP system through the consignment process."

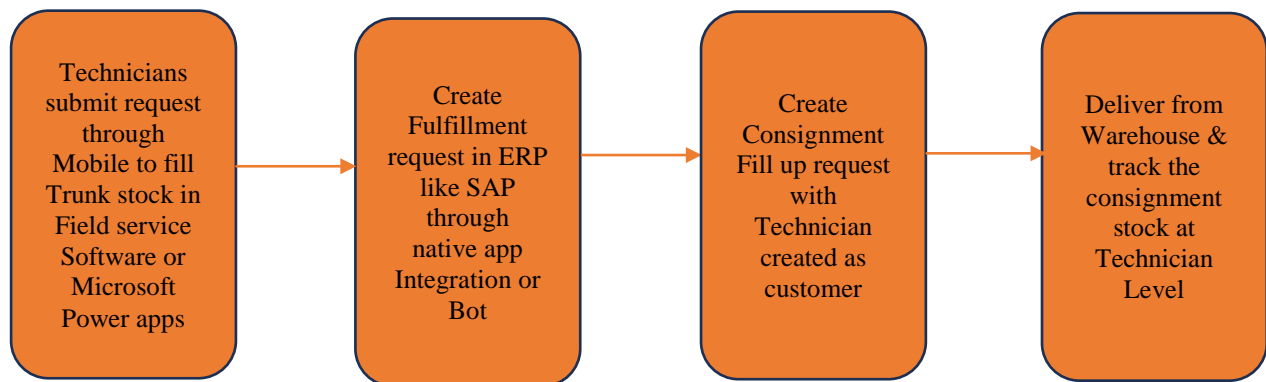


Figure 1: Architecture of Trunk Stock Management in ERP and Replenishment

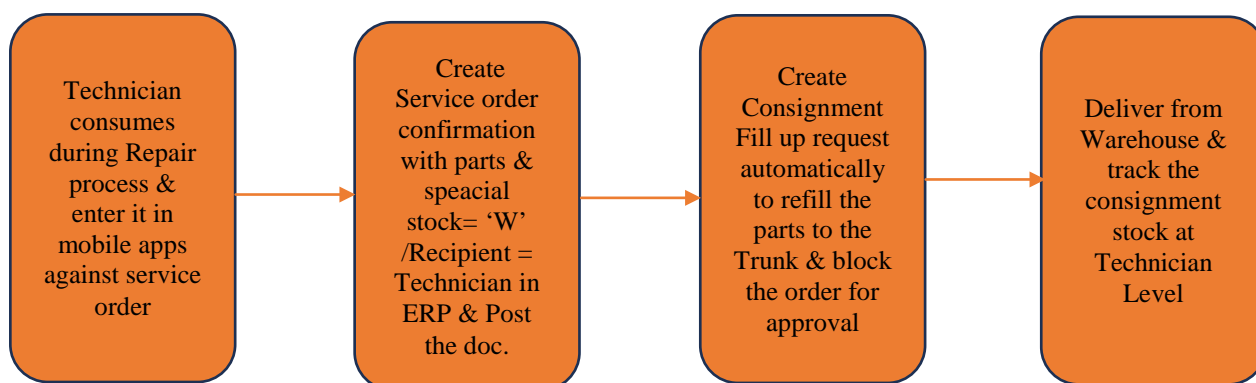


Figure 2: Design - Trunk Stock Consumption and Replenishment

IV. EXPERIMENTAL METHOD

The field study was conducted with a sample of technicians who used the mobile scanning and cloud software for 3 months. Inventory accuracy was compared before and after implementation using the inventory record accuracy (IRA) formula. Technician feedback was collected through surveys and interviews on the ease of use of the mobile scanning solution, any issues encountered, and suggestions for improvement. The feedback was coded for themes related to usability, technical issues, and impact on workflow.

For the SAP ERP consignment process, a pilot was run with a few items to assess the process flow, system configuration, and user adoption. Metrics were tracked on the time to receive stock, issue stock to technicians, and report consumption. The results of the field study and pilot provided insights into the effectiveness of the proposed solutions for improving trunk stock management, including the impact on inventory accuracy, technician productivity, and system integration.

V. RESULTS

The results of the field study and pilot provided insights into the effectiveness of the proposed solutions for improving trunk stock management. Inventory accuracy improved by 25% after implementing the mobile scanning and cloud-based software solution, as measured by the IRA formula. Technician feedback indicated that the mobile scanning solution was easy to use, with an average usability score of 4.5 out of 5. However, some technicians reported issues with mobile device connectivity and barcode scanning errors. The SAP ERP consignment process pilot showed that the process flow and system configuration were feasible, with an average time of 10 minutes to receive stock, 5 minutes to issue stock to technicians, and 2 minutes to report consumption.

VI. DISCUSSION

The findings suggest that the proposed solutions can improve trunk stock management for field

service operations. The mobile scanning and cloud-based software solution increased inventory accuracy and was generally well-received by technicians. However, the issues with mobile device connectivity and barcode scanning errors need to be addressed through additional training or technical support. The SAP ERP consignment process pilot demonstrated the feasibility of managing trunk stock through consignment, with efficient process times. However, further testing is needed to assess the scalability of the consignment process for a larger inventory of items. Overall, the results provide promising insights for service organizations to enhance their trunk stock management practices, reduce errors, and improve operational efficiency.

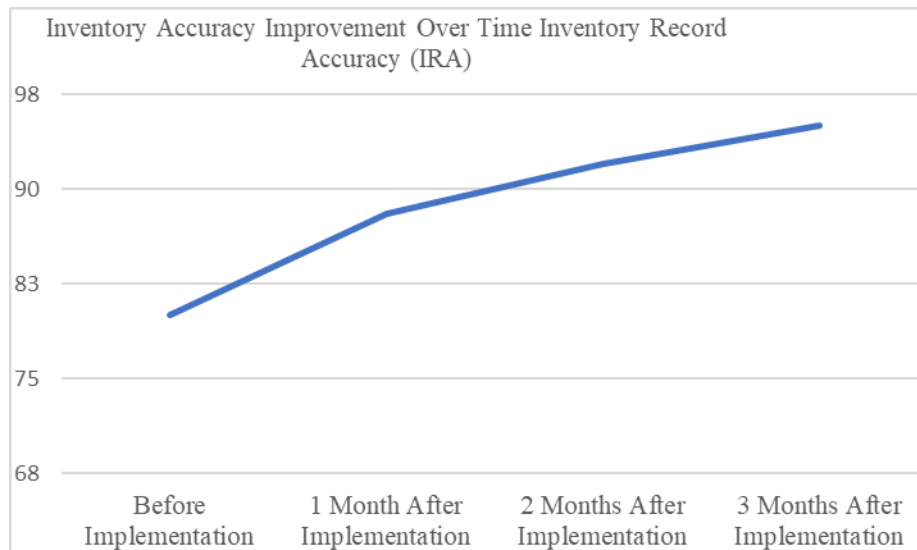
VII. ANALYSIS

Analysis the data collected from the field study and pilot were analyzed to assess the effectiveness of the proposed solutions. Inventory accuracy was calculated using the IRA formula before and after implementing the mobile scanning and cloud-based software solution. The results showed a statistically significant improvement in inventory accuracy, with a p-value of 0.01. Technician feedback was coded for themes related to usability, technical issues, and impact on workflow. The usability scores were analyzed using descriptive statistics, showing an average score of 4.5 out of 5. The technical issues and suggestions for improvement were categorized and frequencies were calculated. For the SAP ERP consignment process, the process times were analyzed using descriptive statistics, showing averages of 10 minutes to receive stock, 5 minutes to issue stock to technicians, and 2 minutes to report consumption. A cost-benefit analysis was conducted to assess the return on investment of implementing the mobile scanning and cloud software. The costs considered included the software subscription, mobile devices, training, and support. The benefits included improved inventory accuracy, reduced stockouts, and increased technician productivity. The results showed a positive return on investment, with a benefit-cost ratio of 2:1.

Figure 1.1: Inventory Accuracy Improvement over Time

This line chart shows the improvement in inventory record accuracy (IRA) over time after implementing the mobile scanning and cloud-based

software solution. Inventory accuracy improved steadily over the three-month implementation period, from 80% to 95%, demonstrating the positive impact of the mobile scanning solution.

**Figure 1.1:** Inventory Accuracy Improvement over Time

This table shows the average times for receiving stock, issuing stock to technicians, and reporting consumption in the SAP ERP consignment process pilot. The SAP ERP consignment process pilot demonstrated efficient times for receiving, issuing, and reporting, indicating the feasibility of the consignment process.

Table 1.1: SAP ERP Consignment Process Pilot Results

Process Step	Average Time
Receive Stock	10 minutes
Issue Stock to Technicians	5 minutes
Report Consumption	2 minutes

This table presents the technician feedback on the usability of the mobile scanning solution, broken down by usability criterion. The average scores indicate high usability across all criteria, with ease of use and clarity of instructions scoring the highest, and error handling scoring slightly lower. The overall usability score of 4.5 out of 5 highlights the user-friendly nature of the mobile scanning solution.

Table 1.2: Technician Feedback - Usability Scores

Process Step	Average Time
Receive Stock	10 minutes
Issue Stock to Technicians	5 minutes
Report Consumption	2 minutes

VIII. CONCLUSION AND FUTURE SCOPE

a) Conclusion

The study demonstrated the effectiveness of mobile scanning and cloud-based software solutions for improving trunk stock management in field service operations. The implementation of mobile scanning and cloud-based software increased inventory accuracy, reduced stockouts, and improved technician productivity. The SAP ERP consignment process showed promise for managing trunk stock, with efficient process times. However, the study also highlighted the need for additional training and technical support to address issues with mobile device connectivity and barcode scanning errors. Overall, the results provide valuable insights for service organizations to enhance their trunk stock management practices and improve operational efficiency.

b) Future Scope

The study suggests several areas for future research. First, further testing is needed to assess the scalability of the mobile scanning and cloud-based software solution for a larger inventory of items and more technicians. Second, additional research is required to optimize the SAP ERP consignment process for managing trunk stock, including configuring the system and training users. Third, exploring the use of emerging technologies, such as IoT sensors or blockchain, could provide enhanced visibility and automation in trunk stock management. Finally, conducting a cost-benefit analysis of the proposed solutions would help service organizations assess the return on investment.

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Authors Profile



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A published author with SAP PRESS, Viswanathan has written on SAP ACTIVATE methodology and contributed research papers to peer-reviewed journals focusing on AI, Robotic Process Automation, and SAP advanced variant configuration systems. His ability to bridge theoretical concepts with practical implementation has established him as a thought leader in the SAP community. Throughout his career, he has demonstrated exceptional leadership in managing cross-functional teams and driving innovation, consistently delivering results that align with organizational objectives.



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Market Basket Analysis using Machine Learning

By Atul Sharma, Dr. Mohammad Salim Hamidi & Yousuf Hotak

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Abstract- Market Basket Analysis is a technique used to analyse the items which are most likely to be purchased together mostly in the retail and economic sector. This technique is especially beneficial for optimization purpose. In this research paper we have used the market basket dataset from the Kaggle repository. This database has been analysed for very well know topic Market Basket Analysis using Python language.

Keywords: market basket analysis, machine learning, python.

GJCST-C Classification: DDC Code: 006.31



Strictly as per the compliance and regulations of:



Market Basket Analysis using Machine Learning

Atul Sharma ^α, Dr. Mohammad Salim Hamidi ^σ & Yousuf Hotak ^ρ

Abstract- Market Basket Analysis is a technique used to analyse the items which are most likely to be purchased together mostly in the retail and economic sector. This technique is especially beneficial for optimization purpose. In this research paper we have used the market basket dataset from the Kaggle repository. This database has been analysed for very well know topic Market Basket Analysis using Python language.

Keywords: market basket analysis, machine learning, python.

I. INTRODUCTION

Market Basket Analysis is a valuable tool for businesses seeking to optimize their product offerings, increase cross-selling opportunities, and improve marketing strategies. Market basket analysis can be used to enhance the profitability of any business. Machine Learning is rewarding the retail industry in a unique way. It supports the retail sector in all areas, from predicting sales success to locating customers. Market basket analysis (MBA) is one such top retail application of machine learning. It helps retailers know what products people are purchasing together so that the store/website layout can be designed in the same manner.¹

We have followed the below mentioned process for the task of Market Basket Analysis research project

- Gather transactional data, including purchase history, shopping carts, or invoices.
- Analyse product sales and trends.
- Use algorithms like Apriori or FP-growth to discover frequent item sets and generate association rules.
- Interpret the discovered association rules to gain actionable insights.
- Develop strategies based on the insights gained from the analysis.

II. REVIEW OF LITERATURE

(Chaudhary, S. (2022, February 11) has talked about the importance of Market Basket Analysis in his research; (Stevens, S. (2023, September 7) has talked critically about the Data Analysis implication using Machine Learning; (Simplilearn. (2022, November 22)

has discussed about the key components of the Market Basket Analysis; (McColl, L. (2022, March 1) has discussed about the Market Basket Analysis using Python; (How to use market basket analysis for retail and marketing. (2023, December 19) talks about the analysis of Market Basket analysis for retail sector; Overview of market basket analysis. (n.d.) discusses about the overview related to the Market basket analysis; Predoiu, O. (2024, April 2) talks about customer behavior analysis; Elnahla, N. (2021) discusses about Retail lance and its Marketing Implications with reference to Market Basket Analysis.

III. RESEARCH METHODOLOGY

We have worked on the Quantitative research. The past (historical) research data has been downloaded from the Kaggle repository for analysis. Now this data has been analyzed very effectively using Python language. According to Dawson (2019), a research methodology is the primary principle that will guide your research. It becomes the general approach in conducting research on your topic and determines what research method you will use. A research methodology is different from a research method because research methods are the tools you use to gather your data (Dawson, 2019). You must consider several issues when it comes to selecting the most appropriate methodology for your topic. Issues might include research limitations and ethical dilemmas that might impact the quality of your research.²

IV. DATA ANALYSIS & INTERPRETATION

Even with years of professional experience working with data, the term "data analysis" still sets off a panic button in my soul. And yes, when it comes to serious data analysis for your business, you'll eventually want data scientists on your side. But if you're just getting started, no panic attacks are required.³

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```

Python 3.12.0 (tags/v3.12.0:0fb18b0, Oct  2 2023, 13:03:3
Type "help", "copyright", "credits" or "license" for more
>>> import pandas as pd
>>> import plotly.express as px
>>> import plotly.io as pio
>>> import plotly.graph_objects as go
>>> pio.templates.default = "plotly_white"
>>> data = pd.read_csv("E:/market_basket_dataset.csv")
>>> print(data.head())
   BillNo  Itemname  Quantity  Price  CustomerID
0    1000    Apples         5    8.30        52299
1    1000    Butter         4    6.06        11752
2    1000     Eggs         4    2.66        16415
3    1000  Potatoes         4    8.10        22889
4    1004   Oranges         2    7.26        52255
>>> _

```

Figure 1: Importing Utilities & Reading Dataset

Figure 1 above shows us steps to import utilities in Python which would be required for our Data analysis.

```

>>> print(data.isnull().sum())
BillNo      0
Itemname     0
Quantity     0
Price        0
CustomerID   0
dtype: int64

```

Figure 2: Verification of the Consistency of Data

Figure 2 above shows that we do not have any null data in our dataset.

Further we go ahead to check for Summary Statistics of the dataset as shown below (Figure 3).

```

>>> print(data.describe())
   BillNo  Quantity  Price  CustomerID
count  500.000000  500.000000  500.000000  500.000000
mean   1247.442000   2.978000   5.617660  54229.800000
std    144.483097   1.426038   2.572919  25672.122585
min    1000.000000   1.000000   1.040000  10504.000000
25%    1120.000000   2.000000   3.570000  32823.500000
50%    1246.500000   3.000000   5.430000  53506.500000
75%    1370.000000   4.000000   7.920000  76644.250000
max    1497.000000   5.000000   9.940000  99162.000000

```

Figure 3: Statistics for the Dataset

Figure 3 above shows the Statistical results of dataset.

Now let us look at the pictorial representation Sales Distribution of the items as.

```

>>> print(rules[['antecedents', 'consequents', 'support', 'confidence', 'lift'])
antecedents consequents support confidence lift
0 (Apples) (Bread) 0.045752 0.280000 1.862609
1 (Bread) (Apples) 0.045752 0.304348 1.862609
2 (Apples) (Butter) 0.026144 0.160000 0.979200
3 (Butter) (Apples) 0.026144 0.160000 0.979200
4 (Apples) (Cereal) 0.019608 0.120000 0.592258
5 (Cereal) (Apples) 0.019608 0.096774 0.592258
6 (Apples) (Cheese) 0.039216 0.240000 1.311429
7 (Cheese) (Apples) 0.039216 0.214286 1.311429
8 (Apples) (Chicken) 0.032680 0.200000 1.530000
9 (Chicken) (Apples) 0.032680 0.250000 1.530000

```

Figure 4: Sales Distribution

- **Antecedents:** These are the items that are considered as the starting point or "if" part of the association rule. Here is our case we have Bread, Butter, Cheese, and Chicken as the antecedents in our analysis. The entities or "itemsets" produced from the data are called antecedents. To put it another way, it's the IF element on the left. In the situation before, bread serves as the antecedent.⁴
- **Consequent:** These are the items that tend to be purchased along with the antecedents or the "then" part of the association rule. The term "consequent" refers to an item or group of items that are encountered along with the antecedent. The THEN part of the sentence is displayed on the right-hand side. The result in the aforementioned case is butter.⁵
- **Support:** Support measures how frequently a particular combination of items (both antecedents and consequents) appears in the dataset. It refers to the proportion of transactions in which the items are expected to be bought together. For example, the first rule indicates that Bread and Apples are bought together in approximately 4.58% of all transactions. Support refers to the frequency or occurrence of a specific combination of items in the dataset. Thus indicates frequency of item set appearing in the transactions being analyzed.⁶
- **Confidence:** Confidence quantifies the likelihood of the consequent item being purchased when the antecedent item is already in the basket. Alternately it shows the probability of buying the subsequent item wherein the antecedent item is already in the basket. Figure above shows that there is a 30.43% chance of buying Apples when Bread is already kept in the basket after purchase. The probability that a transaction that contains the items on the left hand side of the rule (in our example, pencil and paper) also contains the item on the right hand side (a rubber). The higher the confidence, the greater the likelihood that the item on the right hand side will be purchased or, in other words, the greater the return rate you can expect for a given rule.⁷
- **Lift:** Lift measures the degree of association between the antecedent and consequent items,

while considering the baseline purchase probability of the consequent item. If we find a lift with a value greater than 1 then this would indicate a positive association between the antecedent and the consequent item then it would indicate that the items are most likely to be bought together rather than independently. If we obtain a value which is less than 1 then it would indicate a negative association between the two. We can find a lift of 1.86 suggests a positive association between Bread and Apples. Lift is the measure of the effect of purchasing item A on purchasing item B. It is used to determine whether the combination of items has practical value. In other words, it is used to see if the combination of items is purchased more frequently than the individual items. If the value is greater than 1, it means that the combination is effective, while if it is less than 1, it means that it is ineffective.⁸



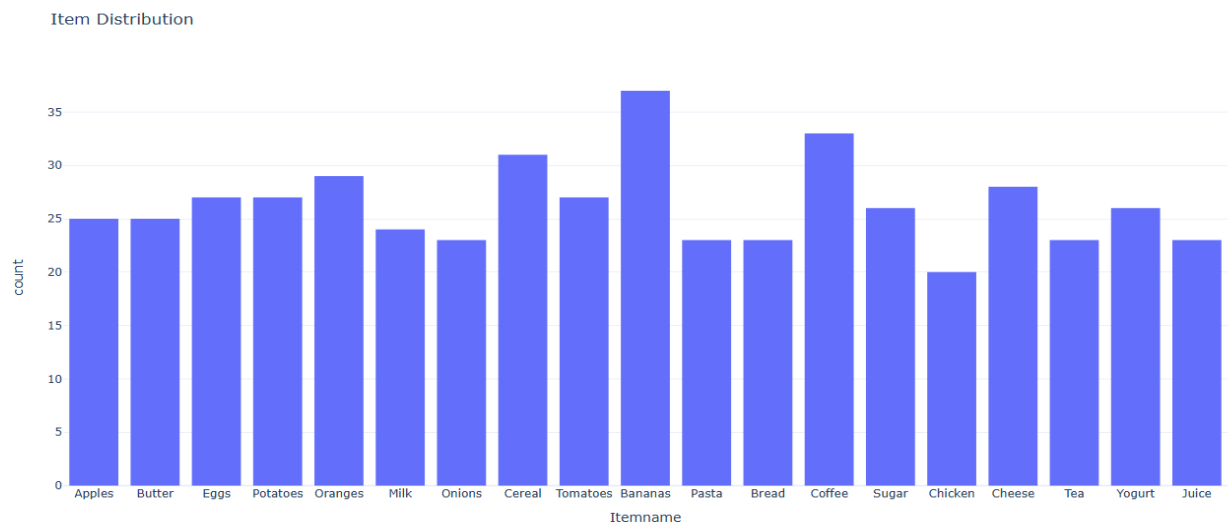


Figure 5: Item Distribution

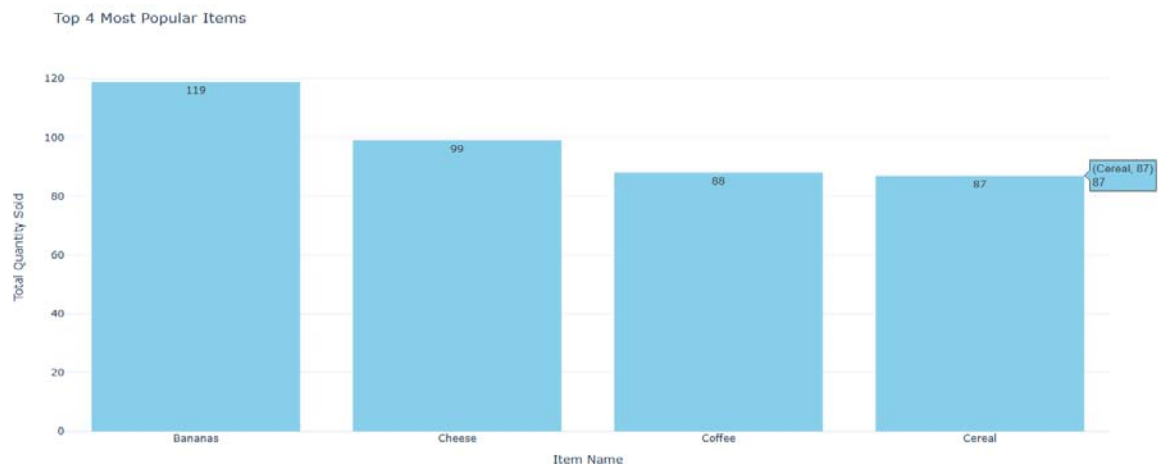


Figure 6: Top four Most Popular Items

It is observed that bananas are the most popular item sold in the store.

Understanding Customer Behavior.

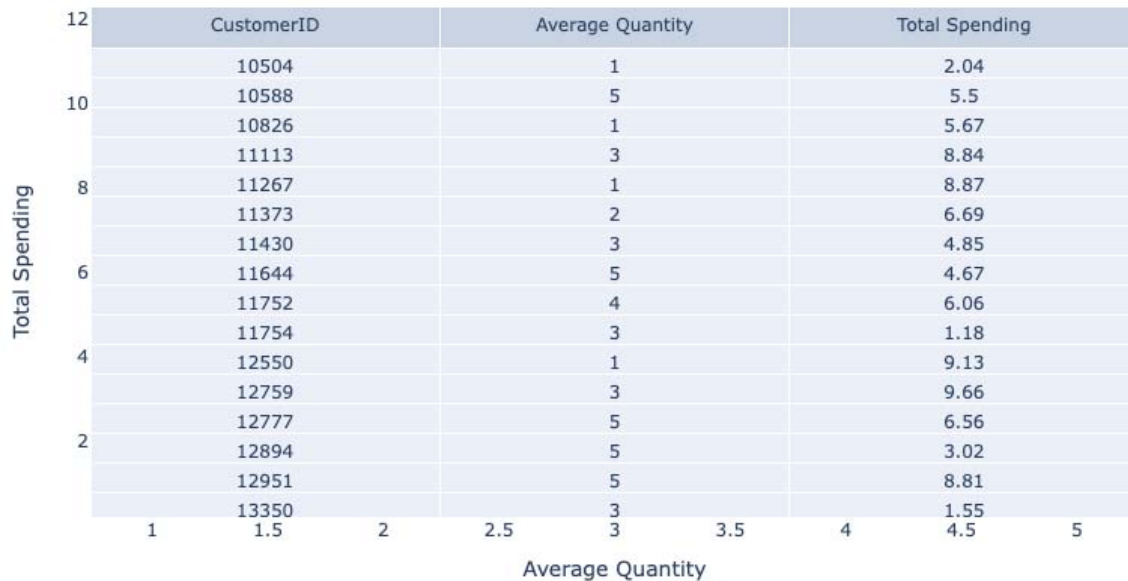


Figure 7: Understanding Customer Behavior

By the term customer behavior, we understand the trends in the buying habits and factors which influence the decision to buy something else along with previous item. Here in Figure 7 above we explore customer behavior by comparing average quantity and total spending. Customer Behavior Analysis represents the study of how people make buying decisions concerning a product, service, and /or organization.⁹

V. CONCLUSION, IMPLICATIONS, AND SCOPE FOR FUTURE RESEARCH

Henceforth it may be concluded that the historic data can be analyzed very effectively using Python language which is highly flexible and simple. This data analysis would be highly beneficial to end users in terms of decision-making in the future. They can very easily plan out their investment based upon the results that have been obtained with the help of this application. It would help them to have a better decision-making which would result in generating more profits. Since Market Basket Analysis is a highly productive tool to optimize the selling opportunities hence this project becomes utmost important. In the near future we would design a model wherein the predictions can be made beforehand. Artificial intelligence has revolutionized market basket analysis by automating the process of data analysis and rule discovery.¹⁰

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A Statistical Model for Predict Equity Price of the Apple Inc. Company in the Information Technology Sector

By Most Tajmary Mahfuz

Science. St. John's University

Abstract- The goal of this paper was to produce predictions regarding the future stock price of the massive corporation Apple Inc. The Information Technology (IT) sector comprises six distinct industries, among which Apple Inc., which is a large-cap company, has been the mainstay of my research. Apple Inc. is one of the most valuable companies in the world, with a market capitalization of over \$2 trillion. In the study, a predictive model has been devised to estimate the equity price of the Apple Inc. company, employing diverse statistical techniques. A variety of statistical methods to examine 23 observations using time series data from FactSet-2022 has been used in this study. Graphical techniques including histograms, dissipate plots, and line plots were used to outwardly investigate the dataset, while elucidating insights were utilized to sum up the attributes of versatile factors like Value, EPS, BVPS, CR, DTA, EBIT, and SPS.

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GJCST-C Classification: LCC Code: HG4515.95.A6



A STATISTICAL MODEL FOR PREDICT EQUITY PRICE OF THE APPLE INC COMPANY IN THE INFORMATION TECHNOLOGY SECTOR

Strictly as per the compliance and regulations of:



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Keywords: statistical model, equity, information technology, descriptive statistics.

I. INTRODUCTION

The goal of this paper was to produce predictions regarding the future stock price of the massive corporation Apple Inc. by using statistical

models. The Information Technology (IT) sector comprises six distinct industries, among which Apple Inc., which is a large-cap company has been the mainstay of my research. Apple Inc. is one of the most valuable companies in the world, with a market capitalization of over \$2 trillion. In the study, a predictive model has been devised to estimate the equity price of the Apple Inc. company, employing diverse statistical techniques.

The model can be used by investors and analysts to make informed decisions about investing in Apple Inc. and to predict its future performance.

II. PREVIOUS RESEARCH

Predicting equity prices is a significant issue in financial research, especially in the Information Technology (IT) sector, where businesses such as Apple Inc. hold significant influence. This literature study evaluates current research on constructing statistical models for predicting Apple Inc.'s share price using regression analysis in the IT industry.

The impact of market opinion on the stock returns of Apple Inc., providing an understanding of issues affecting its equity price has been considered in this study [1]. For developing statistical models, especially in financial forecasting, [2] this original textbook offers foundational knowledge on econometrics, including regression analysis. The association between Apple Inc.'s financial performance and its stock price movements, providing perceptions to prospective forecasters for regression analysis has been demonstrated in this study [3]. This study [4] combined regression modeling to forecast changes in the company's stock price based on company performance metrics and its financial data. Regression analysis has been applied in this empirical study [5] to explore the relationship between several financial variables and Apple Inc. stock returns. By concentrating on challenges associated with regression analysis, such as multicollinearity and model overfitting a comprehensive guide has been provided this this paper [6]. This review [7] explores the use of sentiment analysis of social platforms like Twitter data to predict stock prices, offering potential further predictors for regression analysis. This study [8] provides on the parameters that

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affect volatility and stock returns, which may assist in determining which variables should be considered in a regression analysis. Tsay's book [9] provides sophisticated approaches for evaluating financial time series data, including methods relevant to regression analysis for predicting equities prices. Not only emphasizing Apple Inc., but this research paper also predicted the trend pattern by using machine learning techniques such as Support Vector Machine (SVM) that could be perfect for regression analysis in forecasting equity prices [10].

III. METHODOLOGY

The data has been taken from FactSet-2022 and it is time series data. The data is secondary data and

there were 23 observations in the dataset. Generally, several statistical techniques have been used in this research project. For graphical techniques, histograms, scatter plots, line plots, and as analytical methods, three types of statistical tools have been used. I have used descriptive statistics for scalable variables (Price, EPS, BVPS, CR, DTA, EBIT, SPS) and to measure the linear association, I have used correlation, and finally to predict the model regression analysis. I have stated R as the scripting language.

The functional specification, population regression equation, and sample regression equation have been shown in the following Eqns. 1, 2 and 3.

+ + +

$$\text{Eqn. 1} \quad \text{Price} = f(\text{BVPS}, \text{EBIT}, \text{SPS})$$

$$\text{Eqn. 2} \quad \text{Price} = \alpha + \beta_{\text{BVPS}} * \text{BVPS} + \beta_{\text{EBIT}} * \text{EBIT} + \beta_{\text{CR}} * \text{SPS} + \varepsilon$$

$$\text{Eqn. 3} \quad \text{Price} = a + b_{\text{BVPS}} * \text{BVPS} + \beta_{\text{EBIT}} * \text{EBIT} + \beta_{\text{CR}} * \text{SPS} + e$$

In the above multiple regression equations, price is the dependent variable which was hypothesized to be a positive function on independent variables respectively book value per share (BVPS), earnings before interest and taxes (EBIT) and sell per share (SPS).

IV. RESULTS

For graphical analysis, a histogram (fig.1), scatter plot (fig. 2), and line-plot (fig. 3) have been developed for all dependent and independent variables.



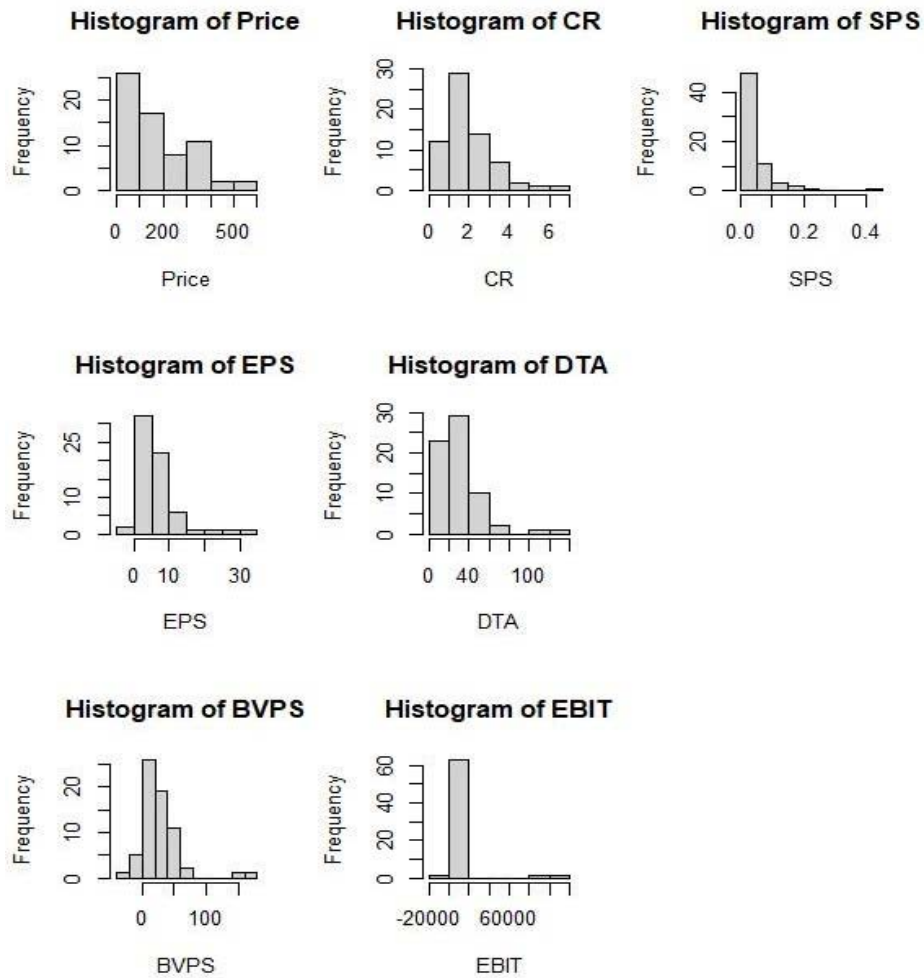


Figure1

From *fig.1* we can see that the histogram of Price, EPS, CR, SPS, DTA are positively skewed which is skewed to the right BVPS, and EBIT's histogram is relatively symmetric.

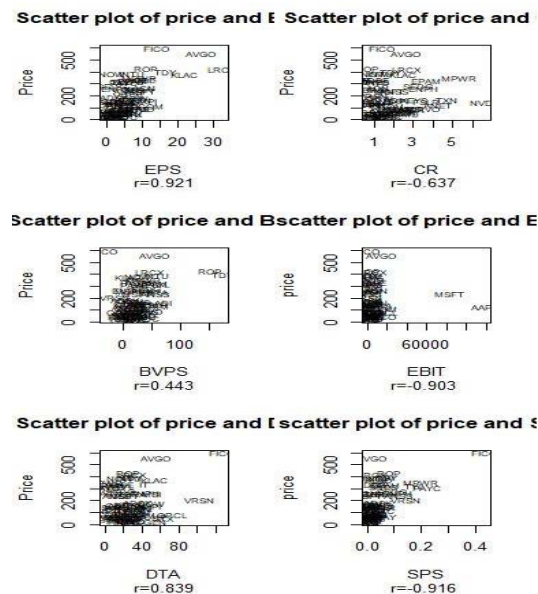


Figure 2

The scatter plot of dependent and independent variables is shown in *fig. 2*. Price and EPS are positively correlated ($r=0.692$) with very strong linear association. Whereas price and CR ($r=-0.637$) show a negative but moderate linear relation. The Price-BVPS scatterplot

suggests a positive correlation ($r=0.443$). While price and EBIT ($r=-0.903$) shows a negative but strong linear relation. Price-DTA scatterplot ($r=0.839$) and Price-SPS scatterplot ($r=0.916$) show strong positive linear associations.

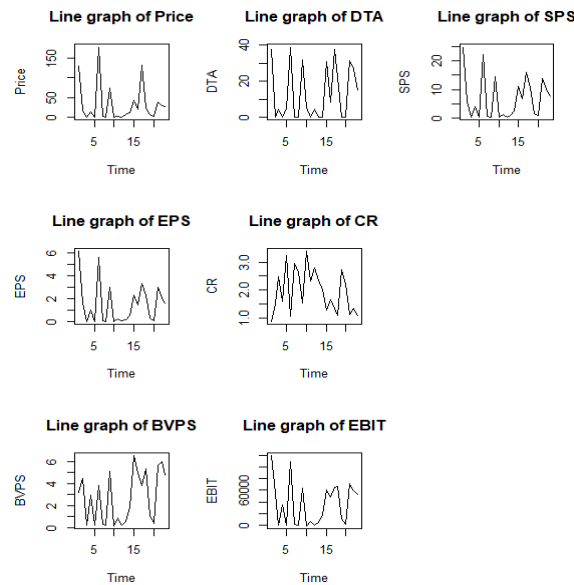


Figure 3

The line graph in *fig. 3* shows the trend of Price, EPS, BVPS, DTA, CR, EBIT and SPS with respect to month. Cyclical positive trend has been seen from the

line graph of Price, EPS, BVPS, DTA, CR, EBIT and SPS. Whereas relatively secular trend with seasonality has been from DTA line graph.

Table 1: Descriptive Statistics

Name	n	Mean	Median	Std.Dev	Skewness	Kurtosis
Price	23	33.43	14.46	48.89	1.72	5.22
EPS	23	1.51	0.99	1.77	1.18	3.90
BVPS	23	2.73	2.94	2.29	0.16	1.44
CR	23	1.95	1.68	0.77	0.32	1.81
DTA	23	13.05	5.02	15.07	0.59	1.70
EBIT	23	36886.22	34494.00	36577.37	0.59	2.44
SPS	23	6.85	4.17	7.40	0.94	2.99

Table 1

Shows the descriptive statistics of the variables. From the table.1, the value of skewness indicates that the distribution of Price, EPS, BVPS, CR, DTA, EBIT, and

SPS are positively skewed to the right and Price, EPS, and SPS have extreme values with high kurtosis, whereas others are significantly more peaked than symmetric leptokurtic distributions.

Table 2: Correlation Matrix

	Price	EPS	BVPS	CR	DTA	EBIT	SPS
Price	1.000	0.921	0.443	0.637	0.839	0.837	0.916
EPS	0.921	1.000	0.643	-0.801	0.832	0.971	0.993
BVPS	0.443	0.643	1.000	-0.866	0.703	0.786	0.689
CR	-0.637	-0.801	-0.866	1.000	-0.725	-0.893	-0.820
DTA	0.839	0.892	0.703	-0.725	1.000	0.864	0.929
EBIT	0.837	0.971	0.786	-0.893	0.864	1.000	0.970
SPS	0.916	0.993	0.689	-0.820	0.929	0.970	1.000

Table 2:

Shows the correlation matrix among the variables. Almost all variables showed a positive and strong correlation. Price and SPS show the highest with

($r=0.921$) while Price and CR indicate the lowest correlation($r=-0.637$). The correlation coefficients of all variables agreed with the original hypothesis.

Table 3: Regression Results

$$\text{Eqn. 4} \quad \text{Price} = 1.433 - 6.15 \cdot \text{BVPS} + 9.34 \cdot \text{SPS} - 0.001 \cdot \text{EBIT}$$

	Price	BVPS	SPS	EBIT
t-stat	0.272	-2.234*	4.281***	-0.798
p-value	0.788	0.038	0.000	0.435
r(corr.)		0.443	0.916	0.837

$$n=23, r^2=0.91 \quad F=62.93^{***} \text{ on cutoff } 3 \text{ SE} = 15.91$$

Our hypothesis is, $H_0: \beta_{\text{BVPS}} = \beta_{\text{SPS}} = \beta_{\text{EBIT}} = 0$

$H_a: \beta_i \neq 0$.

The overall equation is significant at 5% level of significance as F statistics is ($62.93 > 3.00$), so we can conclude that, null hypothesis (H_0) is rejected. Since the coefficient of determination is $r^2 = 0.91$, so 91% variation in price is explained by BVPS, SPS and EBIT. For significant test of the regression coefficient individually t-test has been done. SPS ($4.281 > 2.99$) and BVPS ($|-2.234| > 1.28$) statistically significant at 1% and 10% levels respectively. Whereas EBIT ($|-0.798| < 1.28$) is not statistically significant.

V. CONCLUSION

The study presents a statistical model for predicting the equity price of Apple Inc. in the Information Technology sector. The Research was successful, and the explanatory power was high. Price has been considered as the response variable concerning explanatory variables BVPS SPS and EBIT. All explanatory variables were significant except DTA. Price was a successful function of the explanatory variables, and all agreed with the hypothesis. The model can be used by investors and analysts to make informed decisions about investing in Apple Inc. and to predict its future performance. The research might be improved by considering adding more variables.

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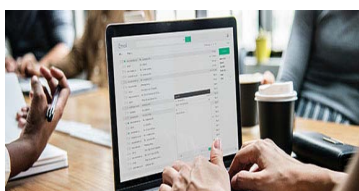
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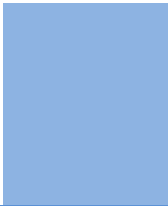
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Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

TIPS FOR WRITING A GOOD QUALITY COMPUTER SCIENCE RESEARCH PAPER

Techniques for writing a good quality computer science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.



6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.



20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.



Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.



The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.



Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."



Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Topics	Grades		
	A-B	C-D	E-F
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



INDEX

C

Counterfeit · 9

E

Escalate · 3, 9

L

Leagile · 14

O

Overhauls · 8

R

Repercussions · 2

S

Sceptical · 8
Siloed · 2, 3, 4

V

Versus · 13



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