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Title: " DIGITAL TWIN IMPLEMENTATION IN HEALTHCARE SUPPLY CHAINS: A FRAMEWORK FOR SAP S/4HANA AND GENAI INTEGRATION"

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REAL-TIME SUPPLY CHAIN RISK MITIGATION IN THE PHARMACEUTICAL INDUSTRY: INTEGRATION OF AI WITH SAP IBP

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Abstract: This research focuses on the extension of AI with SAP Integrated Business Planning (IBP) to address real-time risks in the pharmaceutical supply chain. The literature in the context of the research identifies how the use of these technologies can enhance forecasting, and decision-making as well as ensure business resilience against disruptive factors. Hence, an explanatory research design is adopted where quantitative data from statistics, analysing graphs and qualitative data from case analysis and journals are collected as secondary data. The findings mainly highlight AI and SAP IBP increase the flexibility of the supply chain, inclusive of cost reduction, in addition to giving precise forecasts on risk assessment. There are some challenges encountered including data consolidation, high costs at the early stages and the issue of scale. It is recommended that there should be an emphasis on training the workforce on the adoption of such innovations, step-by-step implementation, and strict data security measures that may support better risk management strategies in the pharmaceutical industry.

Keywords: AI, SAP Integrated Business Planning (IBP), Real-time Risk Mitigation, Pharmaceutical Supply Chain, Predictive Analytics, Supply Chain Resilience.

I. INTRODUCTION

A. Background to the Study

The pharmaceuticals industry is highly vulnerable with regard to the risks that may affect its supply chains. There are some factors that affect the product's availability, quality and conformity. Therefore, real time risk management is needed to ensure the continuation and efficiency of supply chain operations [1]. It brings out an opportunity that can improve decisions, predict any possible disruption in the supply chains, and boost risk management. This research focuses on how integration of AI with SAP IBP can further assist in or contribute to the continuous future stability and flexibility of the pharma industry and minimize risks involved in the supply chain.

B. Overview

This research introduces the concept of AI with SAP IBP to address risk in real time in the pharmaceutical supply chain. The pharmaceutical industry is one that suffers most from its supply chain's disruption, changes in rules and regulations, a change in demand, or some logistical issue about the availability of a product [2]. AI delivers high ‘predictiveness,’ which means risk anticipation and management; SAP IBP is useful in planning, forecasting, and synchronising business activities through supply chains [3]. It also explains how and where these technologies are best implemented to enhance risk management, decision making and supply chain management and recovery capabilities in the case of a threatening event.

C. Problem Statement

The pharmaceutical industry is more vulnerable to supply chain disruptions. This happens from unrelated changes in demand, unexpected alteration of regulatory provisions, and other logistics issues. Most of the time, they lead to shortages, delays, and non-compliance problems. The best traditional risk management approaches fail typically in terms of responsiveness and often poorly predict possible disruptions [1]. The primary purpose of this research is addressing this gap in the real-time mitigation of risk by exploring integration between AI and SAP Integrated Business Planning.

D. Objectives

The objectives of the research are: 1. To evaluate the effectiveness of the integration of AI with SAP IBP to enhance the process of real-time risk management. 2. To examine the impact of AI and SAP IBP on supply chain forecasting and decision-making. 3. To analyze the major issues with the use of AI with SAP IBP and risk management within the pharmaceutical supply chain.

E. Scope and Significance

This study discusses real-time pharmaceutical supply chain risk mitigation. The research will focus on the integration of AI and SAP IBP, examining their scope in assessing the ability to predict and mitigate risks in the supply chain. There are some areas that could be discussed in the application of demand forecasting, inventory management, and supplier coordination. The study will also assess the impact on efficiency, cost reduction, and compliance. This work is significant to pharmaceutical companies for a proactive and data-driven supply chain disruption management approach [3]. Its goal is the improvement of resilience, optimization of planning processes, and supply of products according to demand.

II. LITERATURE REVIEW

A. Real-Time Risk Mitigation in The Pharmaceutical Industry

The pharmaceutical industry needs real-time risk mitigation to ensure uninterrupted supply of necessary medications and maintain patient safety. Disruptions from regulatory changes, change in demand, natural disasters, and supply shortages are some of the risks that this sector has to face daily. As an example, raw material availability became a huge concern for pharmaceutical companies during the COVID-19 pandemic. Nearly 40% of firms suffered disruption in supply chains because of unavailability of raw materials [5]. Advanced risk mitigation strategies in real time can be offered through AI and SAP IBP. It is going to enable companies to predict these disruptions in time and respond promptly. For example, Pfizer managed to ensure the delivery of its COVID-19 vaccine in a timely manner through advanced analytics and AI by effectively managing its supply chain [6]. Pharmaceutical companies would be able to achieve better forecasting and improve their predictive capabilities through leveraging these tools.

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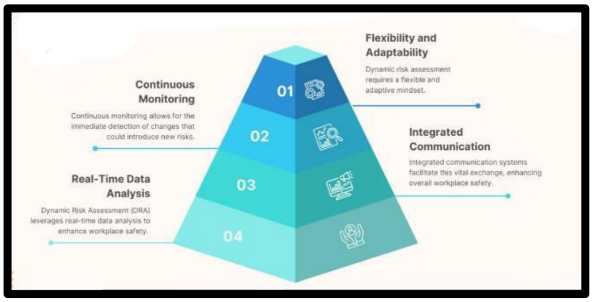

Figure 1: Different Aspects of Real-Time Risk Mitigation

[4]

B. The Impact of AI and SAP IBP on Supply Chain

Integration of AI into SAP IBP is expected to bring a strong impact on the management of the supply chain because it improves accuracy in forecasting, supports decision-making processes, and decreases risk in real-time [7]. It also allows analysis of large data sets, discovery of patterns, and generation of predictive insights based on AI applied to supply chain planning. SAP IBP brings end-to-end visibility and the optimization of processes in the chain with its more advanced planning capability. Together, these will create a very dynamic and adaptive system.

Dynamic Capabilities Theory emphasis is on an organization's ability to integrate, build, and reconfigure internal and external competencies in order to tackle environments that change very rapidly [10]. AI and SAP IBP facilitate the building of such dynamic capabilities as both applications are providing data in real time that gives the companies an understanding about how fast business strategies could be altered for an emerging risk.

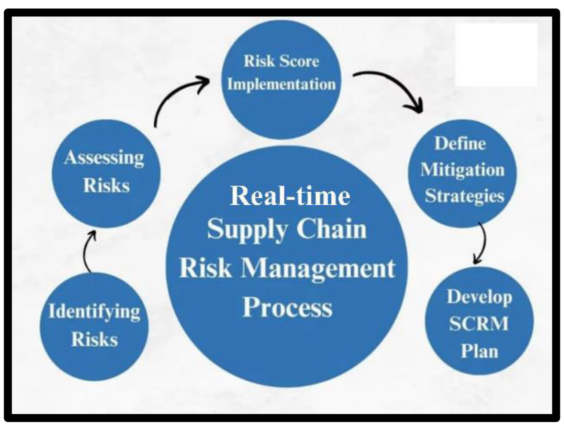

Figure 2: Real-time SCRM Process

[7]

Johnson & Johnson has used advanced analytics and AI in optimising its supply chain operations in order to meet the timely needs of critical healthcare products [9]. It has been able to improve forecasting and production processes, minimizing supply chain disruptions and responding better

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to the fluctuations in demand by combining the planning tools with SAP IBP and AI-driven insights [8]. Artificial intelligence was harnessed during the pandemic to predict and mitigate risks in its supply chain, thus ensuring a steady vaccine and medical supplies availability.

C. Challenges in Implementation of AI and SAP IBP on Supply Chain

The integration of AI into SAP IBP supply chain management is tough, particularly in the pharmaceutical industry. One major challenge is with data integration. Pharmaceutical companies deal with a large amount of data sourced from suppliers, regulatory bodies, and production units [11]. It would be very challenging to integrate this data into a unified system like SAP IBP because it involves ensuring the accuracy, consistency, and compatibility of data across various platforms. Implementation of AI involves a lot of data preprocessing such as cleaning and structuring of data for the machine learning models, which are time-consuming and resource-intensive.

There are more such challenges such as high upfront cost and allocation of resources for technology adoption. AI and SAP IBP require a lot of investment in infrastructure, software, and skilled professionals [3]. These advanced technologies have their learning curve: significant training must be accomplished for employees to really unlock the potential of AI and SAP IBP. This involves change management and organizational resistance issues. Employees will be resistant to new technologies that may lead to job displacement or disruption of current workflows. Hence, the necessity to overcome resistance and build an acceptance culture toward technology is necessary for successful implementation.

Scalability may be another concern. Although AI and SAP IBP have great potential as tools, in large pharmaceutical companies having complex global operations, the requirement is to have the systems effectively scale across supply chains [12]. Companies will be concerned about increasing volumes of data and transactions generated when they grow their operations. These challenges therefore require careful planning, investment in training, and a clear strategy for integrating these new technologies into the existing system to ensure successful implementation.

III. METHODOLOGY

A. Research Design

This study explores the integration of AI with SAP IBP to achieve real-time risk mitigation for the pharmaceutical supply chain through the adoption of an **explanatory research design**. In this context, this is the appropriate research design since it will help in explaining and exploring cause-and-effect relationships in between the implementation of these technologies. The use of this method will be useful because it analyzes how AI and SAP IBP may lead to better forecasting, identification of risks, and decision-making. An explanatory design allows researchers to gain insight into the mechanisms explaining how these technologies affect supply chain operations [13]. This study also allows identifying challenges and opportunities in the integration process. In this regard, this design is essential to ensuring that the study is holistic with the insights that can be brought out regarding the risk mitigation capabilities of AI and SAP IBP in the pharmaceutical supply chain.

B. Data Collection

This research study makes use of secondary qualitative and quantitative data for research regarding real-time risk mitigation in the pharmaceutical supply chain through AI in association with SAP IBP. Secondary qualitative data is based on case studies and journals from researchers in that field to deeply understand how it is being used in practical fields and what difficulties companies are encountering while implementing those technologies [14]. Quantitative data is derived from existing statistics, like graphs and charts which provide evidence on the efficiency of AI and SAP IBP in building supply chain resilience. These data types are going to be combined so that a proper analysis is ensured, as qualitative data help in providing contextual understanding, and the quantitative data provides measurable insight. This mixed approach ensures a balanced view of the research topic, and reliability and validity of findings are improved.

C. Case Studies/Examples

Case Study 1: Digitalization of operations and supply chains

The article shows real-world examples of how digital transformation impacts operations and supply chains. Case studies include practical steps that companies have taken in order to implement digital tools and technologies, including real-time monitoring systems and advanced data analytics [8]. The study demonstrates challenges, including high implementation costs and stakeholder buy-in. Case studies of successful and less successful processes and strategies will reveal the nature of the path leading to the goal of a digital transformation. Details of success stories and setbacks, failures, and failures will make practical lessons from other organizations that undertake their digitalization journeys.

Case Study 2: Predictive analytics and machine learning for real-time supply chain risk mitigation and agility

This study reveals the actual real-world implementation of predictive analytics and machine learning in supply chain agility. The first case in the manufacturing industry explains how successful the use of machine learning models were in predicting equipment failure to avoid the failure of the machine, hence providing proactive maintenance [12]. Another case, in the retail industry, proves how predictive analytics aided in determining fluctuating demand for certain items in order to adjust inventories at appropriate times. These examples underline the success of the proposed strategy in different sectors, prove its adaptability, and outline the real benefits of predictive technologies integrated into real-time risk management systems.

D. Evaluation Metrics

Metric	Description	Purpose
Risk Prediction Accuracy	Measures the accuracy of machine learning models in predicting risks.	To assess the reliability of predictive models.

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Response Time	Time taken from risk identification to mitigation action [3].	To evaluate how quickly risks are addressed.
Operational Downtime	Reduction in downtime due to early risk detection.	To measure the impact on operational efficiency.
Cost Efficiency	Cost savings resulting from proactive risk management.	To determine financial benefits of the approach [3].
Scalability	Ability of the proposed strategy to adapt across different sectors.	To assess the adaptability of the strategy.
Stakeholder Satisfaction	Feedback from stakeholders on the effectiveness of the strategy.	To evaluate stakeholder engagement and buy-in [10].

Table 1: Evaluation Metrics

(Source: Self-developed)

IV. RESULTS

A. Data Presentation

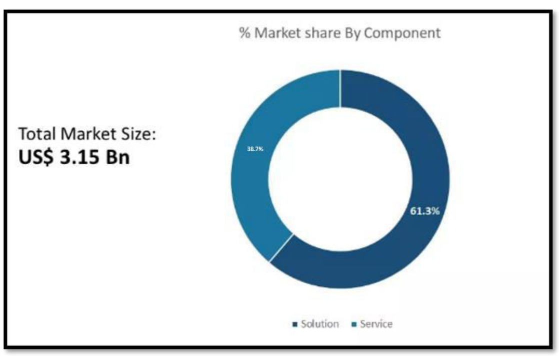

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Figure 3: Supply Chain Risk Management Market Size

[15]

The graph indicates that the growth rate of the global supply chain risk management market would be around 10.2% between the years 2021 and 2031. The market reached the value of US$ 3.15 billion; it is anticipated to almost double by 2031 and will be US$ 6.23 billion, with a CAGR of about 10.2% [15]. This high growth rate indicates the rising demand for advanced risk management solutions with increasing supply chain complexities and real-time risk mitigation strategies. The graph shows an upward trend without any fluctuations, signifying the importance of technologies such as predictive analytics and AI in making supply chains more resilient and efficient across the globe.

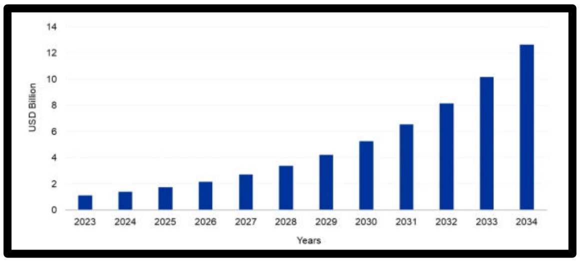

Figure 4: AI in Pharmaceutical Market

[16]

The above graph projects the expected growth of the AI in Pharmaceutical Market from 2021 to 2034. The market is at a smaller level in 2021, but a gradual incremental growth can be observed to cross USD 12 billion in the year 2034 [16]. This increase is brought about by innovations in AI with deep learning, natural language, and context-processing. AI designs molecular structures, prophecies in drug performance and optimises trials for clinical investigations, hence advancing the drug-making process, though cost and risks are minimised at the same time. North America dominates the region, and increasing demand for medicines in the developing regions will escalate growth throughout the forecast period.

B. Findings

The AI and SCRM market are growing rapidly with companies increasingly turning to advanced technology to address a variety of industrial challenges. As supply chains became increasingly complex and the demand grew for real-time solutions to combat risk, the supply chain risk management has gradually expanded [15]. Predictive analytics and AI are crucial tools of resiliency and efficiency across global supply chains. AI is changing the face of the pharmaceutical sector. This accelerates innovation and reduces the costs and risks involved while creating new molecular structures, optimising clinical trials, and predicting drug performance [16]. These trends outline the revolutionary capacity of AI to address specific issues in the industry, making the whole process more efficient and technology-oriented.

B. Case Study Outcomes

Case Study	Key Outcomes

Case Study 1: Digitization Of operations and supply chains	• Real-time monitoring systems along with advanced data analytics lead to more efficient operations and superior decision-making [8]. • Success stories and failures are valuable, practical lessons showing the strategic routes and pitfalls taken by organizations during their digitization processes.
Case Study 2: Predictive analytics and machine learning for real-time supply chain risk mitigation and agility .	• The flexibility of predictory technologies increases supply chain adaptability and firms' risk management structures. • Retail industry case showcases how predictive analytics enhances the inventory management process with demand fluctuation anticipation [12].

Table 1: Case Studies Key Outcomes

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(Source: Self-developed)

The case studies highlight the implications of digitization and predictive technologies in supply chains. They make effective utilization through rate and data analysis, flexibility through dynamic system analysis, and tracking of stock.

C. Comparative Analysis of Literature Review

Author	Focus	Key Findings	Literature Gap
[3]	Data analytics in pharmaceutical supply chains	Explores the application of data analytics in pharmaceutical supply chains, highlighting opportunities and challenges.	Limited research on integrating advanced analytics with real-time decision-making in supply chains.
[4]	Industry 4.0 in pharmaceutical manufacturing	Discusses how Industry 4.0 technologies, such as smart factories, can enhance pharmaceutical manufacturing.	Lack of detailed case studies on the adoption of Industry 4.0 in pharmaceutical firms [4].
[7]	AI in supply chain operations	Examines the role of AI in improving operational	Insufficient analysis of AI's long-term impact on

		efficiency and decision-making in supply chains [7].	supply chain resilience.
[8]	Digitization Of operations and supply chains	Provides insights into how digitization affects supply chain operations through case studies and surveys.	Gap in understanding the integration of digitization across diverse industries in supply chains.
[10]	AI's impact on SME business risks	Explores AI's role in mitigating business risks for SMEs, particularly during the COVID-19 pandemic.	Limited research on AI's application in the supply chain risk management of SMEs [10].
[11]	Digitization in pharmaceutical industry	Focuses on digitization strategies in pharmaceutical industries and the implementation	Need for more practical insights into digitization impacts on smaller pharmaceutical firms.

		challenges.	
[12]	Predictive analytics for supply chain risk	Investigates predictive analytics and machine learning in mitigating risks and enhancing supply chain agility [12].	Insufficient research on real-time applications of predictive analytics in global supply chains.

Table 2: Comparative Analysis of Literature

(Source: Self-developed)

The table offers an outlook of the different researches undertaken in relation to the usability and adoption of digitization. This is a collection of the existing literature on RT-RM opportunities, threats, and gaps that supports supply chain resiliency.

V. DISCUSSION

A. Interpretation of Results

The analysis revealed that there is an expansion of the SCHR and AI market. This may be an indication of the reliance on advanced technologies in addressing the problems of the industry. The necessity of utilising predictive analytics and artificial intelligence for increasing the supply chain robustness. AI is the tool that has noticeably transformed the pharmaceutical industry [16]. These advancements in technology contribute to changing times and trends toward technologically driven industries.

B. Practical Implications

The integration of AI with SAP IBP enables pharmaceutical companies to address risks in the supply chain operation in real-time. This enhances capacity optimization to reduce disruptions while improving their decision-making. With the use of advanced analytics, the organizations can improve its supply chain's resilience, decrease costs, and accelerate drug development, hence increasing efficiency and responding better to changes in the market.

C. Challenges and Limitations

The integration of artificial intelligence with SAP integrated business planning is sometimes complicated and costly. This can be challenging to achieve because data has to be secured, the integration with other systems has to take place and the professionals have to be qualified to the highest levels.

D. Recommendations

Pharmaceutical companies should invest in the training and upskilling of their workforce in managing AI-driven tools [7]. Further, gradual implementation of AI and SAP IBP with robust data security measures can be adopted to smoothen its integration and help realise the benefits of real-time risk mitigation.

VI. CONCLUSION AND FUTURE WORK

In the pharmaceutical supply chain domain, AI combined with SAP IBP reflects major progress in mitigating risks in real-time. It represents how predictive analytics through AI-driven methods make the decision-making process even more efficient and the supply chain much stronger. Integration of the services, which include drug discovery and clinical trials, streamlines those processes making it easier to reduce risks and costs in terms of pharmaceutical product development time.

Future research should be focused on the scalability of AI integration with SAP IBP into various pharmaceutical industries. The investigation of long-term effects on compliance with regulations will also be needed, as well as further AI applications in drug development processes.

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