Assessing Challenges in the Adoption of Artificial Intelligence Technologies in Supply Chain Management

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Abstract*— Artificial Intelligence (AI) has surfaced as a system that can reason, learn, and interact. The interaction and ability to learn from this system enable firms to effectively respond to evolving market demands, potentially giving them a competitive advantage and additional revenue streams. Various industries have also utilized Artificial Intelligence Technologies (AIT) in supply chain management (SCM). AIT in SCM enhances product quality by continuous improvement, managing inventory problems, tackling rising environmental concerns, adapting to consumer needs, and producing unique designs. However, there is a shortage of research examining the challenges encountered while adopting AIT in SCM. To promote the acceptance of AIT in SCM, it is crucial to identify the challenges faced while adopting AIT. This study identifies the challenges through an extensive literature review and expert opinions, aiming to improve awareness and knowledge about AIT's benefits in SCM and make it available for adoption. This study assesses the key challenges by employing the Best-Worst-Method (BWM), where experts identify the most important and least important aspects. BWM ranks the challenges from most important to least important. This research indicates that the top challenges faced were the "false threat of replacement of the human workforce," "lack of standard data collection," and "high investment costs for adoption of AIT." This study aids managers in making more informed decisions to adopt AIT. The findings of this study can also be further used to research/investigate the potential challenges frequently occurring in adopting AIT in specific industries such as manufacturing, construction, finance, etc. One could also examine the interdependence between these challenges and work accordingly to mitigate the potential risks faced while adopting AIT in SCM.

Keywords*— *Supply Chain Management (SCM), Artificial Intelligence Technologies (AIT), Best-Worst-Method (BWM), Adoption Challenges

I. INTRODUCTION

Supply chain management has attracted a lot of interest since the early 1980s [2], and this interest has only increased in the past couple of decades [1]. In the past few decades, we have seen the application

of AIT rise in the area of SC. Applying AIT in the supply chain makes the SC more efficient [3]. However, considerable modifications are required to reap the benefits of AIT. Furthermore, the demands prompt numerous organisations to embrace new artificial intelligence driven strategies or growing technologies. This demonstrates that AIT has already become a top priority for many organisations all over the world [13]. AIT is one of the key factors that provide massive benefits to the industry. AIT is used to automate various processes and predict sales and the number of products manufactured or produced. Therefore, AIT helps in inventory management, supply chain management, marketing management, and many other aspects of an organization. However, even though artificial intelligence is at the boom, not all industries or organizations adopt AIT. This is mainly because they either do not see the advantage of implementing it or do not have the prerequisites required for AIT to work. There are many more challenges faced by various firms.

Specifically, in SCM, the challenges faced during the adoption of AIT include changes in management, acceptance of AIT by humans, current technical constraints, the comprehension of the usability of AIT, and the massive cost of investment for implementing AIT in SCM. In addition, there are significant challenges like concern over security and privacy, absence of transparency, absence of technical standards and capabilities, and insufficient documentation and industrial data [21]. Hangl [20] stated that the implementation of AIT faces many challenges, particularly related to data quality and management, insufficient awareness and confidence in AIT, and resistance to change. These studies are diverse but do not help with a comprehensive study. To tackle the above mentioned issues, this article remedies that situation. This paper starts by reviewing existing AIT in the SCM to identify potential challenges while adopting AIT. These challenges are subsequently assessed by professionals in the fields in order to offer a new and complete framework. With the goal of assisting various stakeholders in the decision-making process, this study utilises BWM to prioritise and evaluate the identified challenges. Thus, this study looks at these challenges and ranks them accordingly using the BWM. This research seeks to examine existing SCM research that utilise AIT and highlight the appropriate fields of SCM applications. Furthermore, it intends to identify the prominent challenges faced in adopting AIT used in the SCM. The following research objectives are:

- To identify the key challenges in implementing AIT in the SC.
- To rank these challenges from the most important to the least important ones.

The study identifies the major challenges in various industries in SC that are adopting AIT. The research also states how, by focusing on these challenges, one could limit the risks if such challenges are already known. This study focuses on identifying and ranking the challenges using the BWM, as it helps in the qualitative ranking of the “best” and the “worst” challenges and ranks the rest of the obstacles quantitatively. The following sections give more details on the challenges of the adoption of AIT in the SCM of various industries. Section 2 provides a detailed literature review on the adoption of AIT in various industries' SCM. The proposed research methodology is discussed in detail in the III section. The application of the methodology with a numerical example is shown in the IV section. The V section explores the results and discusses the outcomes of section IV. Finally, the VI section investigates the conclusions and future research.

II. Literature Review

A. Artificial Intelligence in Supply Chain Management

IBM, in their article "The AI Journey: Artificial Intelligence and the Supply Chain" [36], has defined Artificial Intelligence (AI) as "systems that can actually understand, reason, learn and interact. They use natural language processing and machine learning to learn about and analyse data – and do so at tremendous scale and speed. AI can be taught to correlate this data and extract insights, augmenting the intelligence of the operator". Artificial intelligence has, time and again, proved to have many benefits. Earlier papers on AIT showed how to predict learning curves from neurological variables and vice versa [25]. Quinlan, J. R. [26] showed how artificial intelligence helped deal with noisy and/or incomplete data information. Rabiner L. R. [27] used artificial intelligence for speech recognition. Redmon [29] discovered a unified model for object detection that can do real-time object detection, which makes it a perfect model that applications can rely on for fast and robust object detection. The use of AIT is growing even in the SC sector. A supply chain is a network of flows of goods, services, funds, or data, commencing from the acquiring the raw material of a product to the end consumer. There are many subparts of the supply chain for instance - SCM, SC-analytics, risk-management, etc. Riah [19] stated that the use of AIT is continuously increasing. The methods by which organisations access the three flows of SC are product, information, and fund. AIT is a nascent technology that has significantly influenced SC across all sectors. Riahi [19] also stated that the quantity of research publications is on the rise and that it is imperative to allocate more focus towards AIT in SCM. This growth also extends to employment in the SC and SCM. Therefore, AIT is being used more and more in SC as a fresh approach to both conventional and newly emerging challenges. Yu [8] indicates that the application of AIT in SCM is extensive, covering tasks ranging from procuring raw materials from suppliers to finally delivering them to the customer. AIT has been employed in demand forecasting for several occasions in SC.

Min h. [13] also demonstrates that e-commerce businesses employ AIT to enhance warehousing and logistics, forecast trends, establish pricing and tailored promotions, and anticipate purchase and shipping services without relying on purchase confirmation. The study conducted by N.J. [9] demonstrated that accurate demand forecasting results in higher productivity and minimizes the bullwhip effect of SC, optimise manufacturing and delivery processes, and enhance the performance of the organisation. To overcome challenges such as improving quality with time, inventory management problems, rising environmental concerns, adapting consumer needs, and producing unique designs, the implementation of AITs plays a salient role [7]. Sharma [10] showed that SCM risks are mitigated, and one can better plan inventory management using artificial intelligence. As per Qin [30], administrators should use suitable service models to advice the development of web-based customer care, with the aim of enhancing their marketing efficiently in the online marketplace. Ganesh [11] showed that AIT can also improve risk identification, prediction, and response strategies in a SC. According to Rege [31], AIT is projected to have a major influence on SC in the data-analytics era, and it is anticipated to create fresh prospects for firms in various sectors. Adenekan [12] showed that various AI techniques, such as machine learning, predictive analytics, and robotic process automation, can significantly improve demand forecasting, inventory management, and logistics within SCM.

B.Challenges faced in the adoption of AIT in SCM

Many challenges are faced in the adoption of AIT. According to Shrivastav [22], the cognitive enablement of SCM requires the endorsement of top management, the establishment of enduring partnerships within the organisations, the allocation of specific resources for establishing AI infrastructure, the felicitation of an open channel of collaboration of AIT and data sharing. Bhandari

[33] showed that other challenges, such as management and government support, infrastructure prerequisites, investment costs, customer perceptions, and sustainable packaging, are encountered while adopting AIT in an SC. Organizational factors such as company size, digital skills, and R&D intensity also play a major role in acting as a challenge in adopting AIT [34]. Singh [35] showed that the absence of confidence in the results of AIT, the ambiguous processing and operation of AI algorithm, and unclear benefits and profitability create challenges in the implementation of AIT in SCM. According to Plathottam [32], the rate at which the application is used will be limited by the hazards involved, particularly as it transitions from providing analytical support to controlling industrial operations using AIT. A few researches have been done on the composite challenges faced by SCM. This study aims to report the top challenges in SCM, take experts' opinions, and quantitatively analyse these challenges faced while trying to adopt AIT in SCM.

III METHODOLOGY

After the literature review is done in an organised way, this study utilised BWM to prioritise key challenges while implementing AIT in SCM. The BWM is an MCDM method developed by Rezaei [23]. This is also an MCDM technique that utilises pairwise comparison similar to other MCDM techniques like the Analytical Hierarchy Process (AHP) and Analytic Network Process (ANP), which assess the weights of the challenges. BWM has two primary advantages over these techniques. Firstly, it employs a smaller amount of pairwise comparison, which saves time in computation. Secondly, it delivers a greater consistency ratio. The detailed steps of the BWM are given below [23, 24].

Step 1: Formation of an expert panel.

Step 2: Analyse and identify the challenges by organising a literature review and the opinion of the expert panel. The most important ("best" challenge) and the least important ("worst" challenge) are then selected as per the expert panel. This step identifies the most significant challenge ("best" challenge) and the least significant challenge ("worst" challenge).

Step 3: Finalise a set of challenges as, $\{b_1, b_2, \dots, b_n\}$. This step identifies all the challenges used in the study.

Step 4: Construct a preference vector by rating the best-challenge (most important) over other challenges by assessing specific values ranging from 1 and 9 as:, $= \{x_{B1}, x_{B2}, \dots, x_{Bn}\}$ where, $\{x_{BB} = 1\}$. The preference for best challenges over others is established using a 9-point scale with values ranging from 1 to 9. Level 1 indicates "equally important", while 9 indicates "extremely more important." In the case of multiple decision-makers, we take opinions from each decision-maker.

Step 5: Construct another preference vector of all other challenges over the worst-challenge (least important) by assessing specific values ranging from 1 to 9 as:$X_W = \{x_{1W}, x_{2W}, \dots, x_{nW}\}$ where, $\{x_{WW} = 1\}$. The ranking of the other-challenges to the worst challenge is established using a scale with values ranging from 1 to 9.

Step 6: The optimal-weights of challenges are calculated, $(o_1^*, o_2^*, \dots, o_n^*)$. The optimal weights of the identified challenges conform to the following parameters: For each pair of, ${}^{o_B}/_{o_j}$and, ${}^{o_j}/_{o_W}$ the ideal situation is where, ${}^{o_B}/_{o_j} = x_{Bj}$ and ${}^{o_j}/_{o_W} = x_{jW}$. Thus, in order to approach the ideal scenario

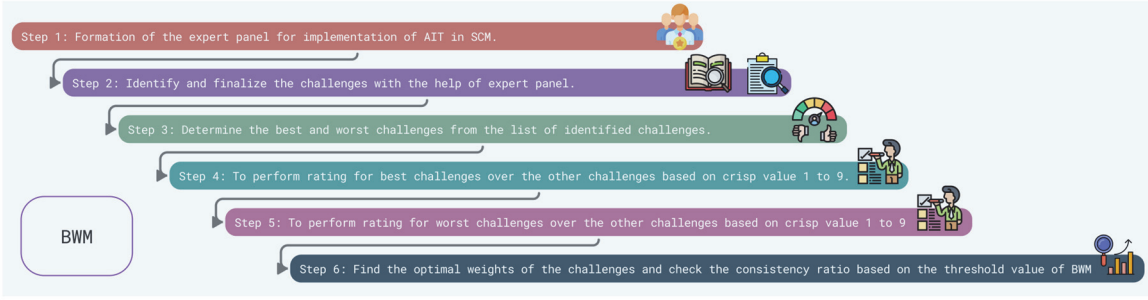
as closely as possible, it is necessary to minimise the highest value within the set of $\{|o_B - x_{Bj}o_j|, |o_j - x_{jW}o_W|\}$, and the formulation of the problem is as follows:

$$\begin{Bmatrix} MinMax_j\{|o_B - x_{Bj}o_j|, |o_j - x_{jW}o_W|\} \\ Subject\ to \\ \sum_j o_j = 1 \\ o_j \geq 0, \forall j \end{Bmatrix} \quad (1)$$

Equation (1) can be converted to the subsequent linear programming problem:

$$\begin{Bmatrix} Min\ \xi_L \\ Subject\ to \\ |o_B - x_{Bj}o_j| \leq \xi_L, \forall j \\ |o_j - x_{jW}o_w| \leq \xi_L, \forall j \\ \sum_j o_j = 1 \\ o_j \geq 0, \forall j \end{Bmatrix} \quad (2)$$

Once "(2)" is solved, the optimal weights $(o_1^*, o_2^*, \ldots, o_n^*)$ and ξ_L^* are derived. ξ_L^*serve as a direct metric for assessing the consistency of the comparison system. As, ξ_L^* approaches zero, the consistency improves and as a consequence, leads to more reliable comparisons. Fig. 1 gives the flow chart of the BWM technique.



[1] Flowchart of BWM

VI. APPLICATION OF BWM

Step 1: The first stage consists of choosing 15 industry experts who have accumulated more than 15 years of professional experience in the field of SCM and 5 years of professional experience in AIT. This research conducted interviews and conversations with the expert panel and collected data by

providing them with information regarding the objective of the study. The relevant challenges for our study were identified and finalized by an integrated, comprehensive analysis of existing literature and by soliciting feedback from expert panels. In total, 8 challenges were identified, as displayed in below Table 1.

CHALLENGES FINALISED AFTER THE LITERATURE REVIEW

Symbol	Challenges	Definition	References
C1	Lack of standard data collection	Establishing a standardised format is required to facilitate the sharing of data across various stakeholders.	[14]; [16]
C2	High investment costs for the adoption of AIT	The cost of setting up AIT in SC and for recycling requires a high investment	[14]; [17]
C3	Securing and retaining the right talent	Many activities in the supply chain require skilled labour.	[32]
C4	False threat of replacement of human workforce	A significant challenge is the prevalent misconception that AI would replace human workers. This misunderstanding might result in criticism and worry among employees, obstructing the successful implementation of AIT in SCM.	[14]; [17]; [18]
C5	Lack of quality Data	Lack of worthy data in the industry that could be used for validating the results from AI	[14]
C6	Already existing technical limitations	Undesired limitation of the utility of a technology due to trade-offs in its technical design	[21]
C7	Lack of trust in AIT outcomes	The lack of trust in outcomes obtained through AIT is also a major obstacle while implementing AIT in SCM because this uncertainty may reduce their acceptance and restrict potential benefits that we can provide to the businesses.	[21]; [17]; [14]
C8	Challenge in replicating the AI models in all nodes of a supply chain	There is a constraint for adopting AIT in SCM for the organizations, organisations are unable to use the same AI models in various nodes of the SC.	[14]; [15]

Step 2: In the second step, the most and the least important challenges are ranked using a questionnaire. C4 was selected as the “best” (most important), and C8 was selected as the “worst” (least important) challenge.

Step 3: In this step, the expert panel rated the most-important challenge over all other-challenges, using a range from 1 to 9. Table 2 shows the agreement of the entire panel of experts to the respond to “best-challenges”.

RESPONSE FOR THE BEST-CHALLENGE

Best to Others	C1	C2	C3	C4	C5	C6	C7	C8
C4	2	3	5	1	8	7	6	9

Step 4: In the fourth step, the expert panel rated the other-challenges over the least-important challenge. Table 3 shows the agreement of the entire panel of the experts to the response to "worst-challenges".

RESPONSE FOR THE WORST-CHALLENGE

Others to the Worst	C1	C2	C3	C4	C5	C6	C7	C8
C8	7	8	4	9	2	3	5	1

Step 5: The optimal weights are evaluated by the BWM optimization model as shown in section 3 using equations (1) and (2), and final weights of identified AIT adoption challenges are displayed in Table 4.

OPTIMAL WEIGHTS OF CHALLENGES

Symbol	Challenges	Weights	Rank
C1	Lack of standard data collection	0.2142	2
C2	High investment costs for the adoption of AIT	0.1428	3
C3	Securing and retaining the right talent	0.0857	4
C4	False threat of replacement of human workforce	0.3427	1
C5	Lack of quality Data	0.0535	7
C6	Already existing technical limitations	0.0612	6
C7	Lack of trust in AIT outcomes	0.0714	5
C8	The challenge in replicating the AI models in all nodes of a supply chain	0.0286	8

VII. Result and Discussions

This study aims to provide a comprehensive understanding to the various stakeholders in the SCM about the challenges faced while adopting AIT in the SCM. This can help them focus on the most relevant challenges and mitigate the risks accordingly. This study focuses on primary research examining the application of AIT in SCM. And the challenges faced while adopting AIT. Initially, this study assesses the optimal weight of the identified challenges, secondly, it ranks these identified challenges based on their values and significance. We determined the relative weights of the challenges and then prioritized them based on their value and importance. Based on the findings, the industry faces three significant challenges: the "false threat of replacing human workforce," "lack of standard data collection," and "high investment costs for adoption of AIT." Conversely, we can view the "challenge in replicating the AI models at all nodes of a supply chain" as the least significant criterion, alongside the "lack of quality data" and the "already existing technical limitations." These low-ranked challenges exist because they will be automatically resolved once the more important ones are resolved. For example, as the threat of human workforce replacement fades and people become more aware of the benefits of AI and AIT, standard data collection becomes necessary, leading to increased investment in adopting AI technologies. This study showed the challenges faced while adopting AI technologies in a SC

VIII. Conclusion and Future Research

The right implementation of AIT is crucial for companies to have a smooth supply chain. Companies face various challenges when trying to adopt AIT in the supply chain. This research identifies these challenges in order of importance. The most important challenges identified using BWM are the "false threat of replacement of human workforce," "lack of standard data collection," and "high investment costs for adoption of AIT." These challenges are critical for instigating AIT in SC. The fear of replacing the human workforce poses a significant obstacle for employees in learning about AIT. To reduce employees' fear of AIT, managers can first focus on imparting knowledge about its benefits. When it comes to deploying the latest technology, investing is substantial. Investment issues also influence the process of data collection. The establishment of data labs and the collection of standard data require significant financial resources. This paper contributes to the supply chain literature by addressing AIT in SC. Although the study discusses various challenges to adoption, it does not address them in terms of implementation. There are several limitations in this study, necessitating further research. The given limitation of numerous possibilities for development can serve as essential bases for future research. Our study used BWM to rank the challenges in adopting AIT in SC, but it lacked quantitative analysis. We subjectively analysed the impact of the challenges but did not conduct a quantitative analysis. Structural equation modeling (SEM) is one process that can validate the model. Another drawback of the study was that there were only a few responses. This research has suggested that future studies should do experimental and case investigation studies in order to verify and further investigate the findings of this study.

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