International Journal of Innovative Research and Scientific Studies, 8(3) 2025, pages: 683-699

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Artificial intelligence-driven resilience: Revolutionizing supply chain risk management in entrepreneurial projects

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Abstract

This paper explores the role of Artificial Intelligence (AI) in supply chain risk management (SCRM) in the context of international entrepreneurial projects across diverse industries. Using a qualitative multiple case study design, the research draws on 20 semi-structured interviews conducted across 10 projects to examine how AI technologies support risk management in dynamic and uncertain environments. Template analysis revealed that entrepreneurial ventures typically adopt a five-stage risk management process: risk mentoring, risk identification, risk analysis, risk mitigation, and continuous adaptation. AI tools facilitate each stage by enabling real-time monitoring (through the Internet of Things), predictive risk identification (via Machine Learning and Natural Language Processing), secure mitigation strategies (using Blockchain and Robotic Process Automation), and adaptive learning (through reinforcement learning). These capabilities allow entrepreneurs to proactively respond to external disruptions, foster operational flexibility, and continuously refine their approaches. As a result, AI emerges as a transformative enabler of agile, data-driven SCRM practices tailored to the unique vulnerabilities of entrepreneurial projects. This study provides a practical framework to guide decision-makers in selecting and implementing AI solutions strategically across the SCRM lifecycle. It offers actionable insights to strengthen resilience, minimize disruptions, and enhance competitiveness in increasingly volatile global supply chains.

Keywords: Artificial intelligence, entrepreneurial projects, risk management, supply chain.

DOI: 10.53894/ijirss.v8i3.6604
Funding: This study received no specific financial support.
History: Received: 26 February 2025 / **Revised:** 31 March 2025 / **Accepted:** 02 April 2025 / **Published:** 30 April 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: The contributions of the authors to this study are as follows: The first author conceptualised the research gap and developed the introduction, methodology, and conducted the data analysis. The second author was responsible for data collection, contributed to data analysis, and prepared the conclusion. The third author contributed to the literature review and participated in the analytical interpretation of the findings. The fourth author contributed to the discussion section and also supported data analysis efforts. All authors reviewed and approved the final manuscript.

Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Institutional Review Board Statement: Prior to data collection, ethical approval was obtained from the Institutional Review Board (IRB). All participants were informed about the purpose of the study and voluntarily provided written informed consent. Confidentiality and anonymity of participant data were maintained throughout the research process in accordance with the university's ethical standards.
Publisher: Innovative Research Publishing

1. Introduction

In today's rapidly evolving business environment, entrepreneurs need to apply the most advanced approaches for effective Supply Chain Risk Management (SCRM) [1, 2]. Among all these challenges, SCRM is a critical domain that companies must prioritize [3]. The globalization of markets has increased supply chain complexity, and the evolving risk landscape requires entrepreneurs to be innovative and adopt adaptive strategies to mitigate risks effectively [4, 5].

Entrepreneurs are directly engaged in initiating and managing businesses that face challenges such as demand fluctuations, supply disruptions, transportation delays, quality issues, and regulatory changes [6]. These risks pose significant threats, including higher operational costs, dissatisfied customers, reputational damage, and potential business failure [7, 8]. Therefore, entrepreneurs must implement robust risk management strategies to systematically identify, assess, and mitigate these threats [9]. This necessitates the adoption of advanced risk management techniques in an increasingly complex business landscape [10].

Previous studies have explored structured risk management frameworks, such as the Committee of Sponsoring Organizations of the Treadway Commission (COSO) Framework and ISO standards, for addressing risks [8, 11]. As well as, the Bow-Tie Analysis for Risk Visualization [12]. Thus, existing research primarily discusses how structured frameworks help in risk identification, assessment, and mitigation, but few studies explore their effectiveness in highly volatile and uncertain entrepreneurial environments [13]. Moreover, while some studies acknowledge the importance of knowledge and data-driven decision-making in Supply Chain Risk Management (SCRM), Ali et al. [14] and Singh [15], they fail to address how entrepreneurs can practically process and utilize large volumes of unstructured and fast-moving data. The traditional knowledge-driven approach is often reactive rather than proactive, lacking predictive capabilities that could help businesses anticipate risks before they materialize [16]. In addition, existing literature does not fully integrate the role of AI in augmenting these structured risk management frameworks, leaving a significant gap in understanding how AI-driven capabilities, such as machine learning and predictive analytics, can enhance SCRM strategies for entrepreneurial projects [17]. Most studies on AI and risk management focus on large corporations or manufacturing firms, with limited research on how AI can specifically support entrepreneurial ventures in managing supply chain risks [9, 18].

From a practical standpoint, entrepreneurial projects often operate in uncertain environments with limited financial and operational resources, making traditional risk management frameworks difficult to implement effectively [19]. Many structured approaches, such as COSO and ISO 31000, require dedicated risk management teams, formalized processes, and extensive documentation, which are often not feasible for startups and small businesses [20]. Additionally, while AI has demonstrated its ability to enhance data-driven decision-making in risk management, entrepreneurs face barriers to adopting AI technologies due to limited technical expertise, high implementation costs, and a lack of understanding of AI's potential benefits in SCRM [2, 17]. Consequently, many entrepreneurial ventures still rely on ad hoc or reactive risk management strategies, leaving them vulnerable to supply chain disruptions, regulatory changes, and market fluctuations [21]. To address these challenges, businesses must leverage AI-driven technological solutions that can process vast amounts of data, extract relevant insights, and enhance risk management capabilities [17]. AI is no longer a futuristic concept; rather, it is a transformative technology with the potential to redefine SCRM and enhance entrepreneurial resilience [16]. By utilizing machine learning algorithms, natural language processing, and predictive analytics, AI can analyze complex datasets, uncover hidden patterns, and generate actionable insights [2]. This enables companies to develop data-driven risk mitigation strategies, improve supply chain visibility, enhance communication, and enable predictive decision-making [2, 17].

Nevertheless, entrepreneurial projects remain in the early stages of AI adoption for SCRM, with existing approaches often being fragmented and underdeveloped [16, 19]. Moreover, there is limited research on how entrepreneurial projects manage supply chain risks and the extent to which AI can enhance their risk mitigation efforts [6, 22]. Addressing this research gap, this study aims to explore the intersection of AI capabilities and SCRM in entrepreneurial projects. Specifically, it seeks to answer the following research questions:

1. How do entrepreneurial projects manage supply chain risks?
2. What is the role of AI in enhancing SCRM within entrepreneurial projects?

2. Literature Review

2.1. Artificial Intelligence (AI)

Artificial Intelligence (AI) is one of those fields whose implications in science fascinate scientists for many years. The real world of AI has witnessed lots of evolution and revolution and the AI is now considerable in the numbers of sectors of the world [23]. 1950s ultrafast forward period, the idea of AI will be edged by the thought of Alan Turing on the tape machine, a milestone study which laid the bricks to create modern computing [24]. Since then AI, which was originally conceived as a theoretical concept, was succeeded by a practical tool used in different applications [25]. People now regard AI as a computer-centric system that is able to flawlessly solve complex issues without juddering or shuddering and it does so at the

right time, accurately and appropriately at a very affordable price with minimal human interference, Mahajan [26]. Chalmers et al. [27] defined AI as the implementation of aims through the system's accuracy to understand data, adjust to the nature of the environment, and master the skill from such similar experiences. Another definition that is widely used provides AI as a gradual growth in the capacity of machines to mimic duties that at least initially is assigned to humans [23].

AI is a diverse and dynamic field that features different tools; some are narrow AI, which can process tasks such as image recognition, and general AI, which is capable of imitating humans [28]. AI provides below, the best-known tools are shown in Table 1. Machine Learning (ML) is undoubtedly a vital part of AI that includes procedures like supervised and unsupervised learning, among others, while Deep Learning uses neural networks containing multiple layers to excel in identifying images and speech [29, 30]. In the Internet of Things (IoT), devices are interconnected and are able to exchange data among themselves [31]. By contrast, Blockchain is a decentralized ledger technology striving to ensure secure and transparent operations [32]. Big data is a term used to describe extremely large sets of data or data sets that are growing in size day by day. It features large-scale data analysis and makes it feasible to make quick and effective decisions across all sectors [33]. Lastly, robotics makes use of autonomous or semi-autonomous machines to boost the production pace [34].

Table 1.
AI's tools in previous studies.

Ref	Machine learning	Internet of Things	Blockchain	Big data	Robotics	Natural Language Processing
Alkalha, et al. [16]				X		
Hasan, et al. [35]	X			X		
Khan, et al. [32]		X	X			
Roozkhosh, et al. [30]	X		X			
Ahamed, et al. [36]	X					
Nalajala, et al. [37]		X				
Sharifani, et al. [38]	X					X
Ballestar, et al. [34]					X	
Pal, et al. [39]			X			
Azizi, et al. [40]		X	X			
Duan, et al. [41]				X		
Edgcomb and Zima [42]	X					

As business companies migrate towards digitalization, it becomes vital to beef up the understanding of the issues of sustainability and business growth, as well as their position in the business equilibrium [43-45]. In these constantly evolving markets and with the tendency to encounter rising competition from global companies [46]. Entrepreneurs need to use the latest high-tech solutions because these solutions might be of a key to market borders and one step ahead for the competitors [47, 48]. Previous studies on entrepreneurs and AI performers have investigated the field of AI and entrepreneurial activities and render the function of AI technologies in business and innovation [49, 50]. Researchers have explored AI adoption trends, challenges, and getting around them. For instance, they have looked at the challenges faced by entrepreneurs who are trying to adopt these technologies [23, 51]. AI and entrepreneurship relate but similarly, there have been research and studies that examine what could be responded from these two some keywords [52]. Today entrepreneur is reliant on AI for data-driven decisions and with its help, predictions and machine learning these decisions are being supported. Furthermore, the effect of AI in ecosystems is another area being discussed as AI-driven technologies disrupt traditional industries, and attract investors towards the market [53]. One of the topics that seems to be of great importance is adjusting AI solutions to the needs of small and medium businesses, allowing them to be more cost-effective but still be able to use the same technologies at the same time [54].

2.2. Supply Chain Risk Management (*SCRM*)

Supply Chain Risk Management (SCRM) is a critical discipline that addresses the complexities and uncertainties inherent in the global flow of goods and services [55]. In today's interconnected and dynamic business environment, supply chains face a myriad of risks that can disrupt operations, impact financial performance, and compromise the overall resilience of organizations [10, 56]. SCRM is defined as identifying potential sources of risk and applying appropriate strategies to reduce supply chain vulnerability with the involvement and collaboration of supply chain partners [57]. The successful implementation of SCRM ensures the integrity of products, services, people, and technologies as well as guarantees the uninterrupted flow of products, materials, information, and finances [58]. Risk Management aims to identify potential risks, reduce them and mitigate their effects, such as possible losses [55]. The ongoing identification of risks and their handling is highly important for all types of organizations [59]. For example, the COVID-19 pandemic has caused great interference and disorganization to the mechanics of most economies, irrespective of their size and phase of development [55, 60]. Dynamic crises such as (cyber) wars and sanctions also act as accelerators for both digital transformation and the emergence of new types of risks [55].

SCRM is a process that comprises of identification, evaluation, and management of risks associated with all stages of the supply chain, from the start of the process, i.e., raw material procurement to the handing over of finished products to final consumers [61]. The first step that should be taken is the risk identification viewpoint. This is also thought to be crucial for

managing risks [62]. The most important goal of risk identification is to discover risks for the supply chain during the process of production [63]. As mentioned earlier, a thorough evaluation and assessment of the relevant risks by using the risk matrix will give a better picture of any and every risk and its relevance [64]. What follows next is the categorization of all the identified risks into two groups: patients who are at high risk of serious complications versus those with low risk of developing any issues at all [65]. At this point, the process generally enters the phase known as risk evaluation. The finding is that the fourth stage of risk mitigation demands for firms to take risks that are practical and help them to curb exposure to the risks using possible and timely means [57]. Efficient risk management helps in establishing the likely points of contention such as determining the factors leading to worldwide economic fluctuations, and these factors may serve as a precursor to tactical planning Yang et al. [10]. Fauzi et al. [62] revealed that risk management among entrepreneurs is crucial in enabling them to catch up with the environmental changes as well as enhancing their dynamic ability.

Enterprise risk management practices positively impact the SME's performance. Enterprise risk management is used as a mediator between financial literacy and SME performance in the study by Kulathunga et al. [63]. Digitalization enables the analysis of huge data, which improves the quality of decision-making in the supply chain [65]. For instance, multiple-criteria decision analysis (MCDA) evaluates the conflicting effects arising from supply chain operations and risks [63]. MCDA has evaluation techniques, which find the best out of known alternative solutions, and design techniques, which represent the problem as a mathematical problem and solve it to find alternatives [66]. Table 2 summarizes risk management in some of the previous studies.

Table 2.
Risk management in previous studies.

Concept	Factors	Reference
Risks Classification	Pure risk	Priyanti, et al. [67]; Um and Han [68] and Zaika, et al. [69]
	Speculative risk	
	Fundamental risk	
	Particular risk	
Processes of risk management	Risk identification	Waqas, et al. [70]; Ali, et al. [14]; Foli, et al. [57] and Ullah, et al. [71]
	Risk assessment	
	Risk mitigation	
	Risk-sharing mechanism	
Risk management tools	Checklists	Masár, et al. [72]; Rachid, et al. [73]; Mascia, et al. [74]; Cervantes-Cabrera and del Carmen Briano-Turrent [75]
	Brainstorming	
	Flowcharts and dependency analysis	
	SWOT analysis	

Traditional approaches to SCRM, such as the COSO ERM Framework, ISO 31000, Failure Mode and Effects Analysis (FMEA), and the SCOR Model, have historically provided structured methodologies for identifying, assessing, and mitigating risks [8, 9, 11]. However, these models are often reactive and less effective in handling rapidly evolving and data-intensive risks compared to AI-driven solutions, which offer real-time monitoring, predictive analytics, and automated decision-making [17]. Taking into consideration the risks faced by entrepreneurial projects differ significantly from those of established businesses due to their higher market and financial uncertainty, lack of historical data, greater supply chain volatility, and limited risk management expertise [4, 15]. These factors make it difficult for startups to apply traditional SCRM frameworks effectively, necessitating AI-driven solutions that can offer dynamic, adaptive risk management without requiring extensive expertise or pre-existing datasets [13]. In the broader context of SCRM, AI presents a transformative opportunity for entrepreneurs by enhancing resilience, improving decision-making, and enabling startups to compete effectively in uncertain business environments. supply chain challenges [55, 76].

Recent studies on AI adoption in supply chain management have highlighted significant advancements in leveraging AI for risk mitigation, optimization, and resilience. For instance, Esa et al. [77] and Shokrollahi et al. [78] provided a comparative analysis of AI in risk management, showcasing how deep learning models such as convolutional neural networks (CNNs) enhance risk identification and assessment processes. Their study emphasizes AI's ability to extract meaningful insights from image data to predict and manage risks, but also notes the limitations in contextual interpretation, advocating for a combination of AI and domain expertise for optimal decision-making.

Additionally, Pasupuleti et al. [79] discussed the application of machine learning (ML) techniques in optimizing logistics and inventory management. They demonstrate that ML models significantly improve demand forecasting accuracy, reduce overstock and stockouts, and enhance order fulfilment prediction. Their findings support the argument that AI-driven predictive analytics and customer segmentation can transform supply chain operations by making them more responsive and data-driven. These studies position the current research within the broader discourse by illustrating AI's growing role in SCRM. However, despite these technological advancements, there remains a practical gap in understanding how entrepreneurial projects, which often have limited resources and expertise, can effectively implement AI-driven SCRM strategies. The existing literature largely focuses on large corporations, while AI's role in mitigating risks for startups and SMEs remains underexplored. By addressing this gap, the current study contributes new insights into how AI can be practically integrated into entrepreneurial supply chains to enhance resilience and agility in uncertain business environments.

2.3. Entrepreneurial Projects

Entrepreneurial projects refer to initiatives undertaken by individuals or groups to create and manage a new business or venture [80]. The accelerated importance of entrepreneurial projects stems from the fact that they generate job opportunities and lead to economic development [81]. for successful entrepreneurial projects, several qualifications must be present for example the ability to accept risk in the face of uncertainty [82]. Additionally, innovation entails the systematic processes through which companies acquire proficiency and implement novel product designs and manufacturing methodologies previously unfamiliar to them [83]. Also, key factors should exist for the success of entrepreneurial projects such as the importance of associating the successful management of an organization and its processes with entrepreneurial management [84]. Entrepreneurial management involves the ability to identify and leverage market opportunities, making the vigilance and market awareness of an enterprise essential for its growth [85]. Consequently, an effective entrepreneurial project, emphasizes collaboration among individual members, a concise set of organizing principles, and decentralized authority within project units [86]. Moreover, proficient problem-solving skills are deemed crucial for fostering innovation and ensuring sustained growth and development within entrepreneurial projects [87].

Furthermore, entrepreneurial projects typically exhibit the features of innovative attentiveness, as they are directed at bringing and introducing new products/services to the market [88]. In addition to that risk is a main factor for it is further entails the possibility of trying something out of the box with unknown repercussions [89]. On the other hand, being flexible, adaptable and well-equipped are essential skills, which allow entrepreneurs to confront challenges and adjust quickly to the new conditions. entrepreneurial projects usually focus on acting in a proactive way, and an entrepreneur in this case would always seek the opportunities and capture them [21]. They generally operate in a changing, dynamic environment. What is more, collaboration and partnership are also considered important because they allow entrepreneurs to build relations, form joined initiatives and exploit various scopes of expertise in order to support the future of their company [55]. In addition, the ability to closely watch the market and trend is crucial for companies to make profits and sustain growth [85]. Consequently, as a project of such nature, the collaboration among team members, a concise set of organizing principles, and at the project level, the decentralization of authority are the dominant structural elements [86]. Additionally, highly-developed problem-solving skills are understood to be as core-elements of innovation and the best for sustaining entrepreneurial projects' growth and development over time [87, 90]. Based on the above discussion, the study framework was developed as depicted in Figure 1.

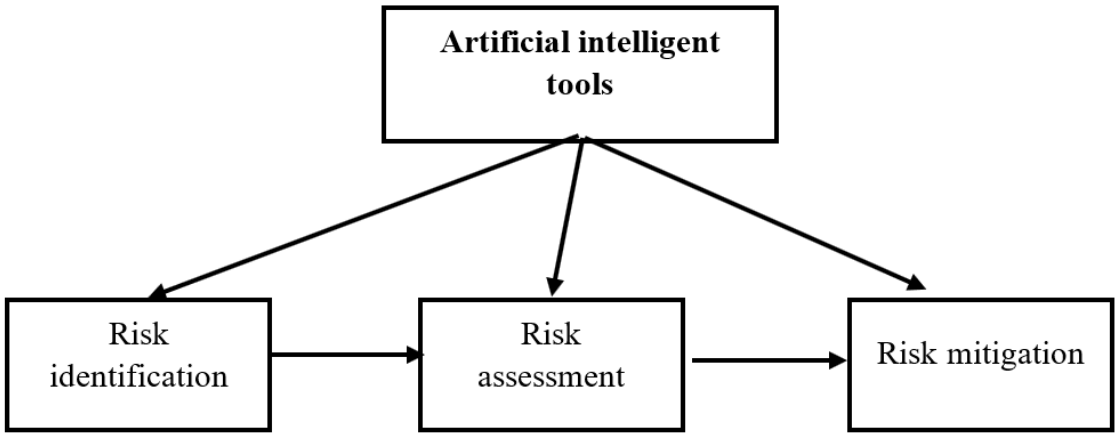

Figure 1.
The study framework.

3. Methodology

This research employs multiple case studies to extract valuable insights through replication [91, 92]. Furthermore, the triangulation in the duplication of case-studies tactics relieves the expected misinterpretations of events [93]. Consequently, adopting a multiple case study strategy facilitates a deeper understanding of real-world scenarios by comparing and contrasting various responses [94].

3.1. Data Collection

The data was gathered from 10 international entrepreneurial projects in diverse industries; namely, Food, Agriculture, Smart Cars' Charger, Delivery, Fashion, Recycling, Mobile Applications, Tourism, Handmade Craft, and Green Energy. A total of 20 interviews with two managers from each company were conducted; namely, the General Manager (GM) and the Information Technology Manager (ITM), serving as respondents. GMs recommended the participation of ITMs as they believed ITMs could provide valuable insights during the interviews.

Data was collected using the convenience sampling technique, ensuring that the data collected was representative of the population from which the sample is drawn [95]. Each interview lasted between 30 and 45 minutes, with follow-up telephone calls and interviews conducted as needed to clarify any incomplete or imprecise information. Data collection was stopped at the point in which no new significant information was emerging [96].

3.2. Data Analysis

Template analysis was employed to analyze the results, generating a coding structure to represent themes consistently with the reviewed literature [97, 98]. Table 3 shows the techniques used to sustain the research's reliability and validity.

Table 3.
The quality of the research design.

Quality of the research design	Case study
Reliability	Use case study protocol
	Interviews transcription
Construct validity	Data triangulation
	Multiple case studies report
Internal validity	Explanation building & pattern matching
	Develop a conceptual framework
	Experts' feedback on the results
External validity	Replication in multiple case studies

Adapted from:
Source: Yin [92] and Creswell, et al. [99]

The primary themes identified were AI and SCRM, as summarized in Table 4.

Table 4.
Template analysis example.

Quotation	Sub-Code	Code	Sub-Theme	Main Theme
"With efficient inventory management, we can track supplies in real-time and avoid stockouts."	Real-time tracking	Inventory management	Risk monitoring	Supply chain risk management
"In the food industry, risks include unpredictable weather affecting crop yields and supplier delays."	Material delays	Supplier risk recognition	Risk identification	
"Through detailed spending analysis, we optimize expenses and negotiate better deals with customers."	Spending analysis	Downstream risk analysis	Risk analysis	
"To mitigate delivery risks, we partner with reliable shipping companies and closely track each shipment."	Shipment tracking	Reduce risk impact	Risk mitigation	
"Continuous improvement in our recycling processes increases material recovery rates and minimizes waste generation."	Material recovery	Recycling improvement	Risk adaptation and continuous improvement	
"By leveraging IoT, we gain real-time insights into our supply chain, allowing us to proactively monitor potential risks and ensure seamless operations."	Real-Time Insights	Proactive Monitoring	Risk Monitoring (IoT)	Artificial intelligence tool
"Coupling machine learning with our extensive database allows us to detect subtle variances and potential risks in the supply chain that might otherwise go unnoticed, providing us with valuable insights for proactive risk identification."	Subtle variances and potential risks	Detect potential risks	Risk Identification (Machine Learning)	
"NLP and Pattern Recognition a process of finding regularities and similarities in data, enables us to extract valuable insights from unstructured data, aiding in understanding customer sentiment and analyzing risks."	regularities and similarities	Risk Understanding	Risk Analysis (NLP & Pattern Recognition)	
"Blockchain ensures transparency and security in our supply chain,	Fraud Risk Reduction	Transparency and Security	Risk Mitigation (Blockchain)	

reducing the risk of fraud and enhancing trust among stakeholders."				
"Reinforcement Learning helps us continuously adapt our risk management strategies by learning from past outcomes, while RPA automates routine tasks, freeing resources for continuous improvement initiatives."	Adaptation by learning and continuous improvement initiatives	Adaptation and continuous improvement	Risk Adaptation & Continuous Improvement (Reinforcement Learning & RPA)	

The analysis examined the gap and overlaps in the implementation of AI among the respondents. The entire dataset was considered in answering the research question, prioritizing themes' ability to capture the research question over their frequency [99]. The frequency of the study theme in the cross-case analysis is shown in Table 5. To minimize bias, the coding was reviewed by three academic experts in the field to assess the analysis process and interpretations' suitability.

Table 5.
Cross-case analysis.

	Supply chain risk management					Artificial intelligence tools				
Project	**Risk monitoring**	**Risk identification**	**Risk analysis**	**Risk mitigation**	**Risk adaptation and continuous improvement**	**IoT**	**Machine Learning**	**NLP & Pattern Recognition**	**Blockchain**	**Reinforcement Learning & RPA**
Food		X	X		X	X		X	X	X
Agriculture	X	X	X	X			X	X		X
Handmade Craft	X					X	X		X	X
Green Energy	X			X	X	X	X		X	
Smart Cars' Charger		X		X	X			X		X
Delivery				X	X	X		X		X
Tourism	X		X	X	X	X	X	X	X	
Mobile Application	X	X	X	X	X	X			X	X
Recycling		X		X	X			X	X	
Fashion	X	X	X	X	X			X	X	X

4. Results

The cross-case analysis strategy was used to answer the study's questions. Thus, this section presents the results of each question.

4.1. How do Entrepreneurial Projects Manage Supply Chain Risk?

The cross-case analysis demonstrated five stages used by entrepreneurial projects to manage the risk of their supply chain as shown in Figure 2.

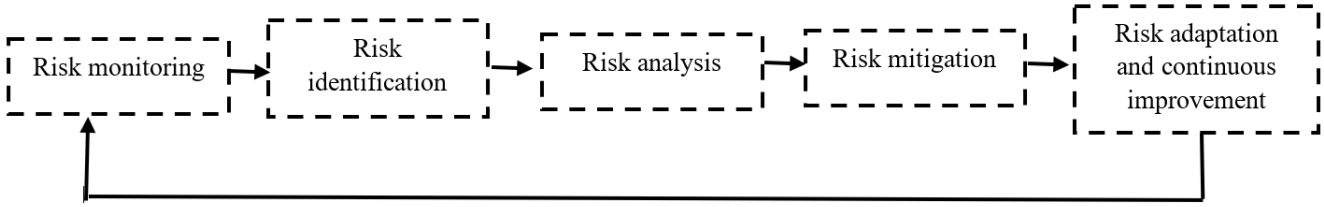

Figure 2.
Supply chain risk management in entrepreneurial projects.

4.2. Risk Monitoring Stage

At this stage, the entrepreneurial projects observe the situation to quickly deal with any risks. As the manager of the handcraft project said, "Monitoring customer feedback and reviews allows us to address any quality concerns and continuously improve our handmade craft offerings." Also, the manager of the green energy project added, "Real-time monitoring of energy consumption patterns helps us make data-driven decisions for demand management and resource optimization." The manager of the fashion project explained, "By closely monitoring supplier lead times, we can proactively address any delays and maintain consistent production schedules for our fashion items."

4.3. Risk Identification Stage

The minoring stage helps the entrepreneurial projects to identify the supply chain risks, as the general manager of the recycling project said, "One of the significant supply chain risks we discovered is fluctuating commodity prices, which can impact our revenue and material sourcing strategies. Not all risks are critical, so we classify them according to their effect." The manager of the smart car chargers project elaborated, "Our risk identification includes potential disruptions in the supply of critical electronic components, which could lead to production delays." The projects identify the external factors that might affect the source of materials, as the manager of the food project mentioned, "We identify supply chain risks such as unpredictable weather events affecting crop yields and potential supplier disruptions due to transport delays."

4.4. Risk Analysis Stage

The results showed that the entrepreneurial projects analyzed the identified risks as the manager of the tourism project said "Utilizing purchasing asper analyses is indeed very helpful information as it allows us to streamline both with our expenditure and even negotiate better deals with lodging providers and transportation suppliers as the market is quite unique and finicky with innovative developments". By using thorough analysis to look for the source of risks, the entrepreneurial projects focus on understanding the factors contributing to quality risks, as it was illustrated by the manager of the food projects, "Through performing in-depth sourcing analysis we can understand the aspects that lead to lower quality risks, particularly because we operate within a volatile and unstable environment".

4.5. Risk Mitigation Stage

The entrepreneurial projects then mitigate the risk to minimize the impact of current and future risks, as the manager of the delivery project said, "To mitigate transportation risks, we optimize our delivery routes and maintain a well-maintained fleet." The mitigation of risks includes implementing a contingency plan, as the manager of the tourism project explained, "We have contingency plans in place to address travel disruptions and secure alternative accommodations for our customers." The manager of the smart car charger added, "We build collaborations with our key partners as a strategy to mitigate the risks." The mobile application manager added, "Resource diversification helped us in reducing our risks."

4.6. Risk Adaptation and Continuous Improvement Stage

The last stages of managing the supply chain risk in entrepreneurial projects are the adaptation and continuous improvement stage, the manager of the smart car chargers said: "Continuous improvement in our manufacturing processes enhances the efficiency of our smart car chargers while minimizing defects. We are considering developing wireless chargers." The manager of the green energy project added, "Continuous adaptation to advancements in green technology enables us to offer cutting-edge renewable energy solutions. We keep learning from our mistakes and the risks we face." The manager of the recycling project explained, "Continuous improvement in our recycling processes allows us to increase material recovery rates and minimize waste generation. However, we face challenges related to cultural change."

What is the role of AI on supply chain risk management in entrepreneurial projects?

The role of AI on supply chain risk management is as depicted in Figure 3.

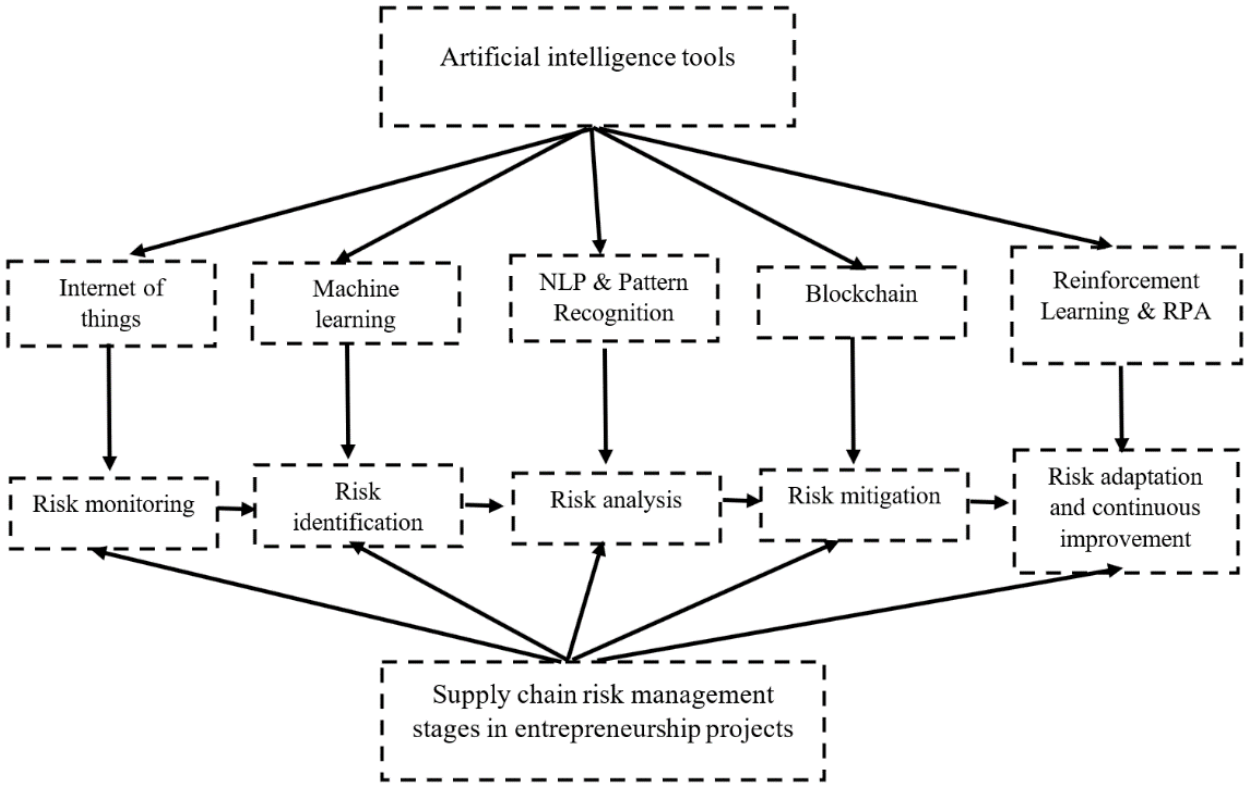

Figure 3.
The role of AI on supply chain risk management.

4.6.1. Internet of Things (IoT) Vs Risk monitoring stage

The results showed that entrepreneurial projects rely on the IoT in the monitoring stage, as the IT manager of the handmade craft project said, “Process and equipment monitoring ensure that our craft production remains efficient and allows us to make timely adjustments for better productivity.” The IT manager of the delivery project added, “IoT sensors track inventory levels to help optimize stock levels and prevent shortages.” The IT manager of the food project explained, “IoT data on customer behavior helps identify emerging market trends.” Thus, the following proposition developed:

P1: The AI tool (IoT) enhances the entrepreneurial projects’ ability to monitor the supply chain risks.

4.6.2. Risk identification vs. Machine learning

The entrepreneurial projects recognize risks through machine learning where the IT manager of the tourism project acknowledged that, “Machine Learning algorithms use past data to identify potential risks before they get worse”. The IT manager in the agriculture project explained how, “Machine Learning can identify risks like crop losses caused by bad weather, supply chain interruption, market demand fluctuations”. The IT of the green energy project added “Machine Learning can consider energy consumption data and market trends to identify risks of fluctuations of energy supply, potential environmental impacts, and changes in energy demand patterns”. Thus, the following proposition was developed:

P2: The AI tool (Machine learning) enhances the entrepreneurial projects’ ability to identify supply chain risks.

4.6.3. Risk analysis vs. Natural Language Processing (NLP) and Pattern Recognition

NLP and machine learning are examples of two technologies used to detect risks as the IT manager of the mobile application said that "NLP can be used to look for insights in customer feedbacks, online reviews, and social media data while pattern recognition can identify repeated patterns that may indicate potential risks such as disruptions in suppliers’ deliveries." The IT manager of the recycling project explained that, "NLP is used to extract details from supplier documents and communications and pattern recognition identifies high-risk suppliers. “Thus, the following proposition developed:

P3: The AI tool (NLP and Pattern Recognition) enhances the entrepreneurial projects’ ability to analyze the supply chain risks.

4.6.4. Risk mitigation stage vs. Blockchain

The blockchain technology is the base layer of entrepreneurial projects that focus on supply chain management risks, as the IT manager of the fashion industry confirmed by saying, “Blockchain is an IT platform that helps us track the whole supply chain journey of fashion products to ensure production is from ethical sources and to prevent counterfeit products from reaching the markets.” Additionally, blockchain can boost food safety by enhancing traceability, thus preventing foodborne diseases, which normally spread quickly before any counteractions can be initiated. Accordingly, the IT manager of the tourism project asserted, "Through incorporating blockchain into our services, we foresee secure and transparent

transactions, which thereafter minimize fraud as well as strengthen customer trust." Thus, the following proposition developed:

P4: The AI tool (Blockchain) enhances the entrepreneurial projects' ability to mitigate supply chain risks.

4.6.5. Risk adaptation and continuous improvement stage vs. Reinforcement Learning & Robotic Process Automation (RPA)

The results revealed that reinforcement learning and RPA are used for continuous improvement and risk adaptation. The IT manager of the mobile application project said: "Reinforcement learning helps us dynamically optimize recycling processes, ensuring continuous improvement in recycling efficiency and reducing waste." Whereas the IT manager of the handmade craft mentioned that "RPA automates order processing, enabling us to focus on continuous improvement in craftsmanship and customer satisfaction." The IT manager of the smart car charger explained, "Reinforcement learning enhances our charging algorithms, adapting to fluctuating energy demands and enabling continuous improvement in charging efficiency." While "RPA automates maintenance scheduling, allowing us to focus on continuous improvement in charger reliability and availability." The IT manager of the green energy project added, "We are working on leveraging machine learning algorithms to enhance our predictive maintenance." Thus, the following proposition developed:

P5: The AI tool (Reinforcement learning and RPA) enhances the entrepreneurial projects' ability to adapt and continuously improve the supply chain risks.

5. Discussion

5.1. How Do Entrepreneurial Projects Manage Supply Chain Risk?

Unlike previous studies that demonstrated three stages of risk management, which are risk identification, risk assessment, and risk mitigation [57, 70]. The results of the current study offer valuable insights into the effective management of supply chain risks in entrepreneurial projects, revealing a dynamic five-stage process. The results showed that the first stage of the risk management process in entrepreneurial projects is risk mentoring. The entrepreneurial projects are keen to be proactive in dealing with risk through continuous monitoring of the external environment. This is due to the critical nature of entrepreneurial projects as most of them are still in the early stages [100]. The next stage is similar to the previous studies, which is risk identification, where entrepreneurial projects classify the risks according to their potential impact. Kiseleva et al. [101] highlighted that the most common risks in the identification stage of entrepreneurial projects are the increase in transportation costs, redundancy in delivery schedule violations, and weak financial ability.

Risk analysis is the third kind of risk management in the entrepreneurial projects stage. The development of a dynamic and flexible risk methodology is crucial when it comes to the risk analysis in entrepreneurial projects, since these particular types of projects pose both the unique internal challenges as well as great potential at their own. Ratten [80] emphasized that an entrepreneurial environment, characterized by innovation, uncertainty, and rapid change, introduces unique challenges that necessitate a tailored approach to risk assessment. Similar to the previous studies, this study demonstrated that entrepreneurial projects mitigate their risk. The results proved that different risk mitigation strategies get employed by entrepreneurial projects in the process of developing collaborations with the main partners, resource diversification, and the development of scenarios. By taking proactive measures to mitigate risks, projects can safeguard their supply chains, maintain operational continuity, and protect their reputation among customers and stakeholders [102].

Unlike the previous studies, this study revealed the importance of risk adaptation and the continuous improvement stage. The intensive interval of risk adaptation and subsequent improvement in business implementation that occurs during the entrepreneurial projects is a critical phase in which dynamic changes and repetitive learning occur. In this stage, entrepreneurs actively adapt to changing environments, fostering a culture of innovation and experimentation. The process involves strategic pivots, leveraging technological advancements, and exploring market expansion opportunities. Chengbin et al. [103] argued that entrepreneurs aiming to run their business ventures by continuous improvement are guided by iterative learning and feedback loops, which enable them to respond to failures and successes, to actions that tend to disrupt the smooth running of setbacks and to the customers' preferential nature. This stage emphasizes not only addressing current risks but also strategically planning for future growth, positioning the project for sustained success in the dynamic and competitive environment of entrepreneurial projects.

5.2. What is the Role of AI on Supply Chain Risk Management in Entrepreneurial Projects?

AI plays a crucial role in supporting the capability of the entrepreneurs' projects in scaling up the disaster handling capabilities for the project supply chain management. Such prompts are to be tailored at every stage of AI development, which solves different sets of problems. Risk management is important for making decisions on timely field readings and proper risk assessment, as well as determining responses and changing risk management strategies. There was a result that entrepreneurs took the risk monitoring stage of their projects to be reliant on IoT. He et al. [104] indicated that IoT sensors and devices enable real-time data and information while leading the entrepreneurs to closely follow their supply chain operations. Sensors and other devices from IoT share the data and information in real time to the operators who can use that data as a basis for decision making. The IoT-based monitoring tools allow decisions to be made which can in turn allow the operators closer to monitor their entire supply chain operations [105]. Modern technologies such as monitoring processes and equipment contribute positively by allowing industries to achieve scheduled production outcomes but also make it possible to do necessary amendments on time. Moreover, the IoT offers inventory management capabilities by tracking stock levels and preventing shortages, particularly for hazardous scenarios. Furthermore, IoT data on customer behavior aids in identifying emerging market trends, helping projects proactively respond to changing customer demands.

The results demonstrated that Machine learning plays a pivotal role in risk identification for entrepreneurial projects. Through studying the information, the machines and the algorithms can readily identify the risks that may become severe; this gives project managers the particularly important power of predicting what is going to happen in the future when they are then unknown. This enables projects to identify various risks, such as weather-related crop losses, supply chain disruptions, and fluctuations in market demand. ML can effectively analyze large-scale data structures and uncover emerging patterns that may not be visible with earlier human ignorance [106]. Additionally, AI applications of NLP and pattern recognition are used by risk analysts at this step. NLP enables the extraction of useful data insights from extremely voluminous and diversified sources like customer comments, reviews and social media profiles, which are then used to assess if the risks are real or not [90]. Pattern detection interrelates with NLP by revealing plausible cases, exemplified in the stock market crises, leading to a drop in the supply chain [107]. Both are necessary in the portfolio of risk-intelligent management; they form a complete toolset that allows projects not only to make wise decisions but also to benefit from the risks.

Furthermore, blockchain technology plays a pivotal role in risk mitigation for entrepreneurial projects. This decentralized and open nature of the blockchain technology facilitates the to be trusted data, making the supply chain more secure [3]. Through blockchain utilization, traceability of the entire supply chain is being encouraged. For instance, in the food industry, blockchain enhances traceability and quickly identifies the source of contamination in case of any foodborne illnesses. Similarly, in the tourism sector, blockchain ensures secure and transparent transactions, mitigating the risk of fraud and enhancing customer trust. The findings showed that the RPA was performing the recurrent tasks, thus, it released the staff who could now put in place superior efforts. For example, in the renewal of smart cars' charger project, the reinforcement learning technique becomes the most important part of efficient charging algorithm as it continues to be adjusted in accordance with the change of energy supply, and RPA automates maintenance profiling and classifies problems, which helps maintenance engineers focus on enhancing charger reliability. According to Dey et al. [108], Reinforcement Learning is dynamic knowledge-based approach, which allow projects to optimize their performance based on data available in real time; this is a way of attainment that builds processes efficiently and minimizes the impact of waste. What follows is an overview of the practical implications of AI tools within SCRM for anyone considering embarking in entrepreneurial projects. Taking advantage of the latest technologies, which include but are not limited to the Internet of Things (IoT), machine learning, NLP, pattern recognition, blockchain, reinforcement learning, RPA, projects can easily build up much more powerful and smart supply chains. These AI tools can deliver information that will transform a project's data-driven decision-making, providing the benefits of risk detection well in advance, adjusting processes, and improving overall operations.

6. Conclusion

The findings of this study highlight the significance of SCRM in entrepreneurial projects. The five-step risk management process that includes risk monitoring, risk identification, risk analysis, risk mitigation, and risk adaptation relentlessly improves, illustrated by examples from different departments, stressing the necessity of a constant and agile risk management approach. By adopting such a structured framework, entrepreneurs can more easily transmit uncertainties and challenges. The result of which is that the competitive advantage and sustainability of the businesses will be enhanced in this ever-changing global economic environment. It not only enhances the existing text on this subject but also can serve as a useful source for businesspeople, practitioners, and scholars who want to become more acquainted with the area of SCRM.

The research covers AI in SCRM for enterprise initiatives as well. According to the study, IoT, machine learning, natural language processing, pattern recognition, blockchain, reinforcement learning, and RPA tools allow the risk management process to be enhanced during the stages of monitoring and continuous improvement. Through the application of such AI-based tools, entrepreneurial projects will end up having resilient and responsive supply chains, which will be empowered with the capacity to proactively rebuff, solve, and freely alter supply chain risks. With the further development in AI technology, next SCRM in several years will no doubt be highly accelerated and will become a trend for successful entrepreneurial projects in the future. The study has several theoretical and practical contributions.

6.1. Theoretical Contribution

The result of this study enriches the current literature by providing a framework that explains how entrepreneurial projects manage their supply chain risk where previous studies fall short to explain how entrepreneurial projects manage their risk. Moreover, this study contributes to the existing body of knowledge on SCRM by integrating AI capabilities into risk management strategies, particularly for entrepreneurial projects, a domain that has received limited scholarly attention. While previous studies have examined the role of AI in supply chain resilience. they have predominantly focused on large corporations with extensive resources and well-established risk management frameworks. This research extends the theoretical discourse by highlighting how AI-driven solutions can address the unique vulnerabilities of entrepreneurial ventures, which face higher market uncertainty, supply chain volatility, and limited access to risk management expertise

Additionally, this study challenges the existing literature on knowledge-based risk management by questioning whether traditional human-driven decision-making remains sufficient in highly volatile and complex supply chain networks. By integrating machine learning algorithms, natural language processing, and big data analytics into risk management, this research introduces a new perspective on how entrepreneurial projects can leverage AI to compensate for their lack of historical risk data and expertise.

Lastly, this study bridges the gap between entrepreneurial risk management and AI adoption, offering a theoretical foundation for future research on AI-driven SCRM frameworks tailored to the specific needs of startups and SMEs. By providing a novel conceptualization of AI as a dynamic enabler of risk resilience, this research lays the groundwork for

further empirical studies exploring how AI can redefine risk management practices across different types of entrepreneurial ventures.

6.2. Practical Contribution

This study makes a significant practical contribution to decision-makers, particularly in entrepreneurial projects, by offering a comprehensive framework to integrate AI-driven solutions into SCRM. In a business landscape where supply chains are increasingly complex and vulnerable to disruptions, the research provides entrepreneurs with actionable guidance on how to identify, assess, mitigate, and adapt to risks effectively using AI tools. By leveraging predictive analytics and machine learning, decision-makers can transition from traditional reactive approaches to proactive, data-driven strategies. AI empowers decision-makers to forecast supply chain disruptions, identify high-risk areas, and implement preventive measures that ensure smoother operations, reducing the likelihood of costly delays or failures [109]. Additionally, AI's capability to continuously monitor market trends, consumer demands, and supplier performance enables entrepreneurs to adapt to real-time changes, fostering agility and resilience. Furthermore, the study emphasizes how AI can enhance collaborative risk management, optimizing relationships with suppliers and partners by sharing real-time data and improving communication, thus reducing supply chain vulnerabilities. By providing practical strategies and tools, this research equips decision-makers with the means to optimize resource allocation and strengthen competitive advantage in an increasingly unpredictable market environment.

7. Limitations and Future Research

Although the research results are important somehow, this study does have some limitations to be considered. The cross-case analysis, despite its insightfulness, tends to neglect some important aspects of entrepreneurial risks. One possible area of future research would be extending the scope of projects selected for review. Moreover, longitudinal studies will have beneficial effects to show how risk management practices develop over time and assess their outcomes in the long run. Moreover, investigating the framework of this study could be fruitful for further research to generalize the findings.

Interview Questions: Adapted from Crovini et al. [9] and Chen et al. [110].

Which types of supply chain risks do you think you are more exposed to?
How are risks managed in the company?
Which types of AI's techniques do you use? And how?
How do you use AI to manage supply chain risks?

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