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MAPPING SUPPLY CHAIN RISKS AND RESILIENCE STRATEGIES FOR STARTUPS USING THE SCOR AND FMEA MODEL: AN INNOVATION HUB PERSPECTIVE

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Abstract:

Background: Startups often encounter significant challenges in developing sustainable and efficient supply chain operations, particularly when resources are scarce and the business environment is in flux.
Purpose: This study explores supply chain risks and resilience strategies within the vibrant startup ecosystem of the IPB (Institut Pertanian Bogor) Startup Innovation Hub in West Java, Indonesia.
Design/methodology/approach: Utilizing a mixed-methods approach, the research includes questionnaires, interviews, and analytical techniques such as Failure Mode and Effect Analysis (FMEA) and Analytical Hierarchy Process (AHP) to identify and prioritize risks.
Findings/Result: The findings reveal that effective supply chain resilience strategies for startups should focus on maintaining quality, enhancing flexibility and promoting sustainability. The analysis highlights that planning processes are particularly vulnerable, underscoring the need for robust forecasting and improved coordination. Innovation hubs are critical in supporting entrepreneurial growth by providing resources and facilitating networking. To navigate these challenges, the study recommends the implementation of a comprehensive Enterprise Risk Management framework and the cultivation of a risk-aware culture.
Conclusion: By continuously refining their risk management strategies, startups can enhance their resilience, promote sustainability, and improve their capacity to manage supply chain disruptions, thereby boosting their growth potential in the innovation landscape.
Originality/value (State of the art): This study is distinguished by its focus on the IPB Startup Centre innovation hub the research offers a cross-sectoral analysis of startups within a single innovation hub which allows the study to identify differences in supply chain risks across various startup types, contributing to a more inclusive understanding of risk management in entrepreneurial ecosystems.

Keywords: innovation hub, startups, supply chain resilience, supply chain risk

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INTRODUCTION

Sustainable supply chain risk management is an important aspect of the overall sustainability of a supply chain. An emerging area of inquiry attempting to identify and mitigate vulnerabilities that threaten environmental, social or economic performance within a complex supply chain. There have been numerous literature reviews conducted to better understand sustainable supply chain risk management. One of the key areas that has been extensively studied is the integration of environmental, social, and economic criteria in supply chain management.

Startups often grapple with the challenge of establishing and maintaining sustainable supply chain operations amidst limited resources, technological constraints, and a rapidly evolving business environment. These young enterprises must manage inherent risks that threaten to disrupt supply chains, which are critical for resilience and sustainability efforts (Darmanata et al. 2010). Supply chains serve as complex networks that connect businesses with suppliers, distributors, and customers, facilitating the sourcing, production, and delivery of products and services. Events such as natural disasters, geopolitical instability, cyber threats, fluctuating market demands, and global crises like pandemics introduce significant risks that can destabilize operations and disrupt the flow of goods, leading to severe financial, operational, and reputational consequences (Hasanah &Setiwan, 2024).

Accordingly, building supply chain resilience is vital for ensuring business sustainability. Resilience building can be defined as the capability to undertake activities and initiatives in an anticipatory way to be better prepared and protected for any internal and external disruptions if they emerged as a strategic imperative for companies, ensuring business continuity even during disruption while maintaining performance. Choirun, (Choirun & Santoso, 2020) provides a comprehensive review of sustainable risk management in the agri-food supply chain, emphasizing the need for a multi-dimensional approach that considers economic, social, environmental, technical, and institutional aspects. But practical implementation barriers persist and resilience capabilities remain underdeveloped in the face of rising sustainability priorities (Raptou et al. 2022).

Innovation hubs, such as business incubators and accelerators, are crucial in supporting startups and encouraging entrepreneurship, particularly in regions like West Java, Indonesia. These centres are vital in nurturing the dynamic startup ecosystem (Wibisono et al. 2018). They provide startups with vital resources such as physical space and access to mentorship programs, where knowledgeable experts offer guidance that significantly contributes to startup growth and development (Rahman & Setiawan, 2020). These hubs create atmospheres that facilitate networking among entrepreneurs, investors, and industry experts, creating opportunities for potential partnerships, collaborations, and investment opportunities, an important factor for startup growth and sustainability (Wirawan & Utama, 2019).

The collaborative forums aid startups in overcoming inherent constraints like smallness of scale, lack of critical expertise or business experience that hinder productivity and growth. Communal office spaces promote practical peer learning, while accelerator programs allow access to specific technical skills, investor connections, and structured monitoring resources otherwise challenging for early-stage ventures to harness alone. However, academics peruse that innovation centres may struggle with uneven value delivery and underutilization of expensive infrastructure investments if activities remain siloed rather than an evolving interconnected local actor networks with universities, government, and industry.

Questions also exist around the complexity of positive impact on startups if mentoring focuses disproportionately on chasing funding rather than developing viable business models. In West Java, a growing startup hub, innovation centres play a pivotal role in assisting the region's entrepreneurial aspirations. But the region faces distinct challenges, including inadequate infrastructure, limited access to financing, and a shortage of skilled talent. Such factors can aggravate supply chain disruptions and hinder startup resilience if not addressed effectively.

As innovation hubs act as springboards providing resources, networking opportunities, and knowledge to quicken the development of competitive startup ventures, it becomes essential to assess risks, establish a more harmonized communication with external stakeholders, and implement comprehensive strategies for capacity enhancement. Efforts like these are crucial for fostering entrepreneurial resilience, robustness, and nurturing growth potential.

This study, conducted within the IPB Startup Centre innovation hub, the IPB centre has the aim of providing integrated services for startups for a period of 2-3 years, and assisting exceptional entrepreneurs who can grow into independent and thriving businesses in their respective fields. This centre focuses on the key areas of tropical agriculture, food, bioscience, and marine products. Based on a June 2020 survey conducted by the Ministry of Research, Technology, and Higher Education, IPB startups have increased by 35% with a survival rate of 43% currently the leading innovation hub in Indonesia (Hasanah et al. 2024).

The IPB Start-up Innovation Hub Centre was selected because it houses a diverse range of startups operating in different business sectors, providing a valuable opportunity to gather data from a variety of startup contexts with the aim to address these gaps by developing a comprehensive framework to measure and map sustainable supply chain risk of the various startups in the innovation hub. By leveraging methodologies such as Supply Chain Operations Reference (SCOR), Failure Mode and Effect Analysis (FMEA), and Analytical Hierarchical Process (AHP), the study seeks to identify risks and evaluate current practices, providing valuable insights for startups to anticipate and adapt to disruptions while maintaining socially and ecologically responsible supply chains.

Sustainable supply chain risk management has been widely studied, but there is a notable absence of research that specifically focuses on startups situated within innovation hubs. This study endeavours to address this research gap by developing a comprehensive framework to assess and map sustainable supply chain risks for startups in the context of an innovation hub environment. The novelty of this research lies in its unique combination of methodologies, which integrates the Supply Chain Operations Reference (SCOR) model, Failure Mode and Effect Analysis (FMEA), and Analytical Hierarchical Process (AHP) to identify and evaluate risks in startup supply chains. This multi-faceted approach provides a better understanding of the complex relationship between supply chain operations, potential failure modes, and risk prioritization in the startup context. This study is distinguished by its focus on the IPB Startup Centre innovation hub, which specializes in tropical agriculture, food, bioscience, and marine products. This specific context enables us to explore how sector-specific challenges intersect with the unique constraints faced by startups, yielding insights that are both theoretically rich and practically applicable. Unlike previous studies that have concentrated on established companies or specific industries, our research offers a cross-sectoral analysis of startups within a single innovation hub. This method allows the study to identify commonalities and differences in supply chain risks across various startup types, contributing to a more inclusive understanding of risk management in entrepreneurial ecosystems. By examining supply chain risks through the lens of an innovation hub, we bridge the gap between startup development literature and supply chain risk management research. This novel perspective enables us to explore how the supportive environment of an innovation hub influences a startup's ability to anticipate, adapt to, and mitigate supply chain disruptions.

The urgency of this research is underscored by the rapidly evolving global business landscape, where startups play an increasingly vital role in driving innovation and economic growth. In regions like West Java, Indonesia, where the startup ecosystem is burgeoning, understanding and mitigating supply chain risks is crucial for fostering sustainable entrepreneurial growth. The COVID-19 pandemic has further highlighted the vulnerabilities in global supply chains, making the development of resilient strategies for startups even more pressing. By focusing on the IPB Startup Centre, this study provides timely insights into sector-specific challenges and opportunities for enhancing supply chain resilience in areas vital to regional development and food security.

METHODS

This study employed a mixed-methods approach, utilizing both questionnaires and interviews to collect data from startup businesses operating within the IPB innovation hubs or incubation centres. Mixed methods deliver a more complete understanding of research study by integrating quantitative data with qualitative data and qualitative data can also explain the 'why' and 'how' behind the tendencies found in the data, adding more depth and apt to the findings. Finally, the integration of qualitative and quantitative data can provide a more nuanced interpretation of results, through the identification of potential relationships that may not be apparent when using a single method. The target population consisted of startups housed in the centre. The data collection process involved two primary techniques.

First, a structured questionnaire was administered to the startup representatives to gather quantitative data. The questionnaire covered various aspects related to their supply chain operations, risks, resilience practices, and demographic information. Additionally, semi structured interviews were conducted with key personnel from the startups to obtain qualitative insights and in-depth perspectives. The interviews allowed for a more comprehensive understanding of the challenges faced and strategies employed. Non-probability, to which convenience sampling method was employed to select the participants. From a total of 25 startup businesses housed 20 were chosen to participate in the study. This approach enabled the inclusion of diverse startup ventures operating across various sectors and supply chain domains. The quantitative data obtained from the questionnaires were analysed using the Supply Chain Operation Reference (SCOR).

The SCOR is a model for mapping supply chain activities in businesses. In its use, it helps understand, measure and improve the key supply chain process. According to Paul (2014) there are five basic components or key Supply Chain Operations Reference which includes: 1) Plan is the process of making a plan and then implementing it; 2) Source is the process of ordering, sending, receiving, and transferring raw materials, sub-assemblies, goods and or services to fulfil requests; 3) Make is the process of adding value to the product; 4) Delivery is a process to fulfil the demand for goods and services, and 5) Return is the process of moving goods back from consumers to deal with product defects/ damage and handling of grazing, namely the purchase of products to suppliers.

Failure Mode and Effect Analysis (FMEA) method. This systematic technique helped identify potential risks, their causes, and effects, enabling the prioritization of risk mitigation strategies. The Analytical Hierarchy Process (AHP) was employed using the Super Decisions software to derive weighted priorities according to experts and evaluate the relative importance of different factors influencing supply chain sustainability and resilience. A mixed-methods strategy, combining quantitative and qualitative data to provide a more wide-ranging understanding of the startup supply chain landscape. The Supply Chain Operations Reference (SCOR) model's application to startup operations, offers a standardized approach for analysing diverse startup supply chains across various sectors.

The integration of the Analytical Hierarchy Process (AHP) to derive weighted priorities, providing a nuanced understanding of the relative importance of different factors in startup supply chain sustainability and resilience. Therefore, SCOR was chosen for its comprehensive coverage of supply chain processes and its adaptability to various business models, making it particularly suitable for analysing diverse startup operations. FMEA was selected for its systematic approach to risk identification and prioritization, which is crucial in the high-risk environment of startup operations. AHP was employed due to its ability to handle complex decision-making processes involving multiple criteria, which is particularly relevant when evaluating the multifaceted nature of supply chain sustainability and resilience in startups. The Analytic Hierarchy Process (AHP) and Failure Mode and Effect Analysis (FMEA) are two commonly used risk analysis methods. While each has its own strengths, using them together can provide a more robust risk assessment. AHP allows decision-makers to structure complex decisions into a hierarchical framework to systematically evaluate alternatives based on multiple criteria. It derives priority weights for criteria and alternatives through pairwise comparisons. This helps capture both qualitative and quantitative aspects of risk. However, AHP alone does not fully address the technical details of potential failure modes. FMEA focuses on identifying potential failure modes, causes, and effects early in the design process. It rates risks based on severity, occurrence, and detection. This helps prioritize the most critical failure modes for corrective action. However, FMEA may overlook some higher-level criteria in its analysis. Combining AHP and FMEA can help overcome their individual limitations.

The research framework for this study is illustrated in Figure 1. This framework outlines the systematic approach we employed to address the research objectives. As shown in Figure 1, the study began with a comprehensive literature review to establish the theoretical foundation and identify key concepts related to supply chain risks and resilience in startup contexts. This was followed by data collection through both quantitative (questionnaires) and qualitative (interviews) methods, targeting startups within the IPB innovation hub.

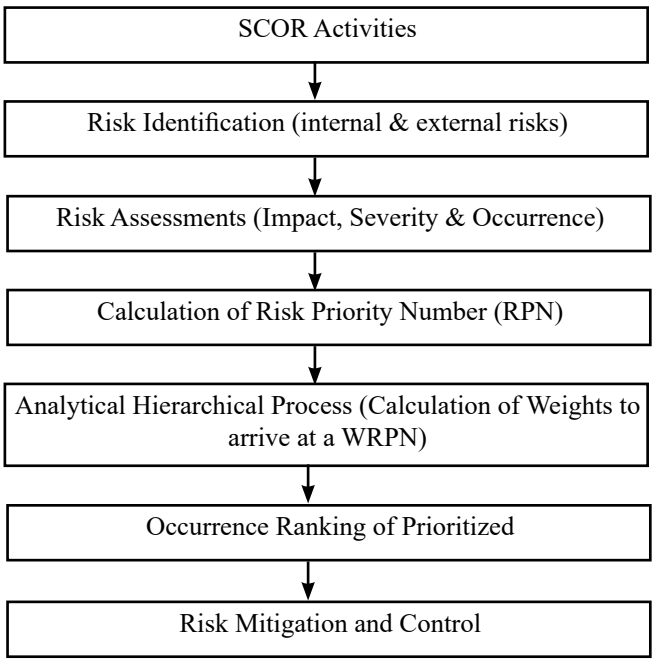

Figure 1. Research framework

The core of the analysis, as depicted in the central part of Figure 1, involved the application of multiple analytical techniques. We utilized the Supply Chain Operations Reference (SCOR) model to map supply chain processes, providing a standardized view of the startups' operations. This was complemented by the Failure Mode and Effect Analysis (FMEA) to identify and prioritize potential risks. The Analytical Hierarchy Process (AHP) was then employed to derive weighted priorities for these risks, offering a better understanding of their relative importance.

The framework also highlights the iterative nature of our analysis, with findings from each step informing subsequent stages of the research. This approach allowed us to develop a comprehensive understanding of supply chain risks and resilience strategies specific to startups in the innovation hub context. The final stage of our framework, as shown in Figure 1, involves the formulation of recommendations based on our integrated analysis, aimed at enhancing supply chain resilience for startups within innovation hubs.

The interview guide shown in Table 1 put FMEA topics into non-FMEA language and ensured that data gathered would be familiar to the startup respondents. For example, the respondents would be asked “What do you see as potential problems? How severe are the problems? How often do you think this might occur? How could we detect the problem or know about it?”. After which the alternatives were run with AHP using experts in the study, the interview guide is shown in Table 1. For the FMEA procedure, each major heading in the FMEA has a comment box that provides instructions. Scales were developed for the severity, likelihood of occurrence and likelihood of detection columns as shown in Tables 2, 3 and 4. The initial FMEA template and guidelines were developed using information gathered from published articles.

RPN was calculated as Severity × Occurrence × Detection. RPN = S×O×D. Weight was derived through expert assessments run through AHP software. Weighted risk priority number is the multiplication of RPN with the weights. Hence WRPN= RPN×W. Ranking shows the overall risk position of each risk process. According to (Liu et al. 2013) failure modes that have a higher RPN are assumed to be more important and given higher priority than those with a lower RPN. Analytical Hierarchy Process (AHP) was used to analyze the relative importance of various factors influencing startup success and resilience, as indicated in the Table 5. A pairwise comparison matrix was created to evaluate the importance of different factors. For each criterion and sub-criterion, pairwise comparisons were conducted to determine their relative importance concerning RPN values on the scale of 1-9. Consistency ratios was assessed to ensure the validity of responses. The calculation of the consistency index ratio (CI) and the consistency ratio (CR) for each comparison matrix in order to measure if the ratings provided by the decision makers are jointly constant.

$$CR = CI/RI$$

Therefore, comparisons are assumed internally coherent when the value of (CR) ≤ 10% have better level of consistency. The AHP algorithm generated weights for each factor influencing startup success and resilience within the IPB Startup Centre based on their relative importance. Weights derived from the AHP is multiplied by the risk priority number to arrive at the weighted risk priority number hence WRPN=RPN× Weights.

Table 1. FMEA Worksheet

Risk Faced	What are the effects of the risk	What causes it	How do you control it	Have you taken actions towards it	How severe is it	How does it occur	How do quick do you detect these issues

Adopted from Anugerah et al. (2022)

Table 2. FMEA degree of risk severity ranking

Degree	Severity	Ranking
Very High	When failure mode affects safe operation of the supply chain.	9
High	Major disruption of service, resulting in re-work	7-8
Moderate	Major disruption of service. Customer is made uncomfortable or result in damage to equipment	5-6
Low	When a failure will cause only slight problem to the customer	3-4
Minor	When a failure is not likely to cause any real effect	1-2

Adopted from Anugerah et al. (2022)

Table 3. FMEA degree of risk occurrence rating

Chances	Description	Probability	Ranking
Very high	Failure is almost inevitable	1 in 3	9
High	Mostly associated with processes or production similar to previous processes that have often failed	1 in 8 1 in 20	8 7
Moderate	Mostly associated with processes similar to previous processes which have experienced occasional failures, but not in major proportions	1 in 80 1 in 200 1 in 400	6 5 4
Low	Isolated failures associated with similar processes	1 in 1500	3
Very low	Only isolated failures associated with almost identical processes	1 in 3000	2
Remote	Process is "similar" to previous processes with no known failures	1 in 6000	1

Adopted from Anugerah et al. (2022)

Table 4. FMEA degree of risk detection ranking

Detection	Likelihood of detection	Ranking
Almost impossible	No known controls available to detect failure mode	10
Very remote	Very remote likelihood current controls will detect failure mode	9
Remote	Remote likelihood current controls will detect failure mode	8
Very low	Very low likelihood current controls will detect failure mode	7
Low	Low likelihood current controls will detect failure mode	6
Moderate	Moderate likelihood current controls will detect failure mode	5
Moderately high	Moderately high likelihood current controls will detect failure mode	4
High	High likelihood current controls will detect failure mode	3
Very high	Very high likelihood current controls will detect failure mode	2
Almost certain	Current controls almost certain to detect the failure mode. Reliable detection controls are known with similar processes.	1

Adopted from Anugerah et al. (2022)

Table 5. Basic rating scale for pair wise comparison of variables in model

AHP scale of important to comparison pair (a_{ij})	Numeric rating	Reciprocal
Extremely important	9	1/9
Very strong to extremely	8	1/8
Very strong to important	7	1/7
Strong to very strong	6	1/6
Strong importance	5	1/5
Moderate to strong	4	¼
Moderate importance	3	1/3
Equally to moderately	2	½
Equal importance	1	1

RESULTS

Startup Demographics and Business Profiles

From the survey results in Figure 2, it shows the type of business focus in the IPB startup centre. 35% are into agriculture businesses, thus selling seedlings etc, 25% are into consumer goods such as packed snacks, natural juices and cosmetics. 15% are into technology and social media handlers and 15% into transportation services, cleaning and housekeeping and final 5% into fashion items.

The study involved 20 startup businesses operating within the IPB Startup innovation hub in West Java, Indonesia. Out of the 25 startups housed in the centre, 20 were selected based on their willingness to participate and their ability to provide comprehensive data across all aspects of the study. This sample size ensured a balance between representativeness and the depth of analysis possible within the study's timeframe These startups represented diverse sectors, including technology, handicraft, food and fashion. The majority (80%) were in the early stages of their venture, having been established within the past three years.

This diversity in the startups business domains and maturity levels provided a comprehensive perspective on supply chain challenges and strategies across various business sectors and growth phases. Out of the survey, 60% of the startups were own by males and the remaining 40% by females with 50% of them between the ages of 20-30 years Indicating the willingness of young people to engage in entrepreneurship. 50% of the respondents were first degree holders with 20% master degree holders and the remaining being senior high school holders.

Assessing Supply Chain Risks and Resilience

To address the first research objective, the Supply Chain Operations References (SCOR) framework, Failure Mode and Effect Analysis (FMEA) methodology was employed to identify, evaluate, and prioritize potential risks affecting the startups' supply chain to map, operations. The severity, occurrence, and detection ratings were calculated, and Risk Priority Numbers (RPNs) were derived for each risk factor. Additionally, the Analytical Hierarchy Process (AHP) was utilized, leveraging the Super Decisions software, to derive weighted priorities for the various risk factors based on their relative importance. The multi-criteria decision-making technique allowed for a comprehensive evaluation of the risks by incorporating inputs from expert.

While the SCOR model provides a robust framework for analysing supply chain operations, it was observed that startups in innovation hubs face unique challenges that are not fully captured by standard SCOR categories. Therefore, a set of custom sub-criteria based on an extensive literature review, expert interviews with startup founders and innovation hub managers, and analysis of startup-specific supply chain issues were developed.

This different approach involved identifying risk factors particularly relevant to the startup context, such as 'lack of product-market fit' and 'changes in market trends,' which are not typically emphasized in traditional supply chain risk assessments. These startup-specific sub-criteria were then mapped onto the SCOR framework, creating a hybrid model that maintains the structural integrity of SCOR while incorporating the nuanced realities of startup supply chains. The categorization process involved a collaborative effort

with supply chain experts and startup mentors from the IPB Startup Centre. For each sub-criterion, it was carefully evaluated to determine its primary impact area within the SCOR model (Plan, Source, Make, Deliver, or Return). This process allowed to maintain alignment with established supply chain management principles while introducing startup-specific considerations. For instance, 'lack of product-market fit' was categorized under 'Plan' as it primarily affects strategic planning and demand forecasting. 'Changes in market trends' was also placed under 'Plan' due to its impact on long-term strategic decisions. This tailored approach enables a more targeted and relevant analysis of risks and resilience strategies in the startup context, addressing a gap in existing supply chain risk assessment methodologies.

Table 6 and 7 shows the findings of risk process that the IPB startups faces. This risk process was mapped within the SCOR activities to give a more comprehensive view of the analysis. The FMEA analysis revealed that the highest-ranked risks for the startups were related to Plan activities within the Supply Chain Operations Reference (SCOR) model. These risks included demand forecasting inaccuracies, ineffective supply planning, changes in demand and customer preferences, lack of product market fix and single source overdependency. The high weighted priority number for these risks highlight the significant challenges startups face in effectively planning and aligning their supply chain operations, which can have cascading effects on other areas such as sourcing, production, and delivery. Comparatively, the risks associated with Source, Make, Deliver, and Return processes received lower risk priority numbers, indicating relatively lower severity or higher detectability compared to planning-related risks. However, it is crucial to note that these risks still pose considerable challenges for startups and should not be overlooked in building resilient supply chains The findings align with previous studies that have identified demand forecasting and supply chain coordination as critical areas of concern for startups and small businesses (Sharma & Bhat, 2014; Shanker et al. 2021). The limited resources and expertise available to startups can exacerbate these planning challenges, making it difficult to effectively manage supply chain dynamics and respond to disruptions.

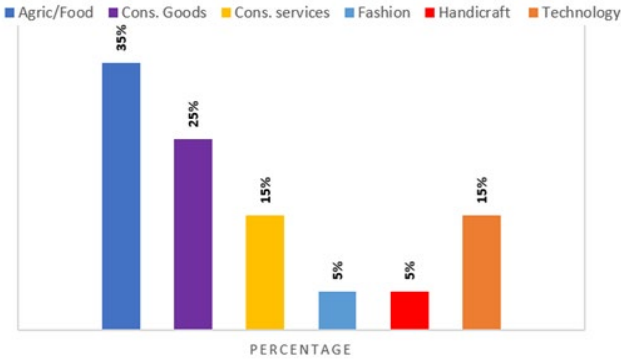

Figure 2. Business Focus in IPB Centre

Evaluating Current Practices and Proposing Enhancements

To address the next research objective, qualitative data from interviews with startup representatives were analysed using thematic analysis. This approach aimed to identify current practices, challenges, and opportunities for enhancing supply chain sustainability and resilience within the IPB startups innovation hub ecosystem.

Table 8 showing the sustainable supply chain strategies that the startups undertake to enhance the business towards a more sustainable and resilient one. The data indicates that the resilience practices identified align with several key features of supply chain resilience theory and best practices. Maintaining quality and compliance practices is crucial for ensuring operational excellence, avoiding risks associated with product quality and regulatory non-compliance, and meeting customer expectations (Manuj & Mentzer, 2008). Flexible supply chains are better equipped to respond to changes in demand, disruptions, and supplier concerns. Redundancy in critical areas serves as a buffer against unforeseen catastrophes (Pettit et al. 2013) Continuous innovation enables firms to adapt to changing market demands and potentially develop solutions to disruptions (Sheffi, 2005). Sustainable operations and resource optimization strategies align with the Triple Bottom Line (TBL) framework's concepts, which emphasize incorporating economic, environmental, and social issues into corporate operations (Adwiyah et al. 2023).

Table 6. Calculation of Risk Priority Number (RPN)

Criterion	Sub-criterion	Risk Process	S	O	D	RPN	Weight	WRPN	Rank
Plan	Strategic risk	Wrong market demand	5.62	5	5.13	144.15	0.014	2	16
		Changes in market trends	6.57	4.71	5.14	159.06	0.108	17.11	6
		Changing customer preferences	5.85	5.57	4.85	158.03	0.134	21.19	4
		Lack of product-market fit	5.33	4.6	6.83	167.46	0.472	79.06	1
	Operation Risk	Delayed raw material delivery	6.75	3	5	101.25	0.037	3.72	13
		Single source dependency	5	6	7.5	225	0.010	2.23	15
		Quality variability	4	4	7.5	120	0.054	6.49	10
Make	Financial risk	Machine breakdown	5.25	3.85	5	101.06	0.738	74.55	2
		Poor materials planning	5.2	3.4	5.25	92.82	0.027	2.28	14
	Production & quality risks	Production delays	6.5	7	5.25	238.88	0.008	1.93	17
		Quality issues	6.67	4.5	5.5	165.08	0.025	4.06	12
Delivery	Distribution	Inventory and cash flow imbalances	6.7	4.42	5.28	156.36	0.067	10.43	8
Return	Customer reverse logistics	Dissatisfaction with returns process	7.2	6	5.6	241.92	0.0473	11.44	7
		Environment concerns with disposal of returned products	6	5.33	7	223.86	0.095	21.20	3
Source	Supplier and environmental risks	Environment disasters	5.2	4.8	5.4	134.78	0.140	18.90	5
		Supplier unreliable	4.4	4.75	5	104,50	0.088	9.23	9
		Geopolitical tensions	5	6.5	6.5	211,25	0.028	5.87	11

Note* (S-Severity, O-Occurrence and D-Detection)

Table 7. Calculation of RPN and WRPN

Risk Criterion	Weights	Ranking	RPN	Ranking	WRPN	Ranking
Plan	0.40377	1	1219.1	1	492.24	1
Source	0.25634	2	450.53	4	115.49	2
Make	0.13116	3	799.96	2	104.92	3
Deliver	0.06673	5	156.36	5	10.44	5
Return	0.13116	4	465,78	3	61.09	4

Table 8. Supply Chain Practices implemented by Startups

Category	Sustainable Practices	No. Startups
Quality and Compliance	- Compulsory ISO 9001 & Quality standard Specifications	16
Supply Chain Flexibility and Redundancy	- Diversification of Suppliers	13
	- Agile Operations	11
	- Made to Order Production	6
	- Contingency Planning	9
Innovation and Product Development	- Innovation in Products Development	8
	- Research & Development	9
Sustainable Operations and Resource Optimization	- Eco-sourcing & Waste Minimization	11
	- Green & Eco Production	11
	- Circular Economy Principles	12
Collaboration and Transparency	- Collaborative Networks	16
	- Supply Chain Traceability & Sustainability Management	13
Digital Transformation and Technology Adoption	- Technology Adoption	14

To develop the categories for sustainable supply chain strategies in Table 8, a systematic qualitative content analysis approach was employed. This method allowed to synthesize insights from a diverse range of sources while maintaining a focus on the unique context of startups in innovation hubs. This included an extensive review of peer-reviewed articles, industry reports, and case studies focusing on supply chain strategies, with particular attention to those relevant to startups and innovation ecosystems and a panel of supply chain experts and startup mentors from the IPB Startup Centre to review and refine the initial categories. This step ensured that the categorization scheme was both theoretically sound and practically relevant to the startup context. And based on expert feedback, final adjustments were made to the categories, ensuring they comprehensively captured the range of sustainable supply chain practices identified in the literature while remaining specific to the startup ecosystem. This personalized approach allowed the development of a categorization scheme that bridges the gap between general supply chain literature and the specific needs and constraints of startups in innovation hubs. By integrating insights from academic literature with practical knowledge from the startup ecosystem, we created a novel framework for understanding and analysing sustainable supply chain strategies in this unique context

Digital transformation and technology implementation play a significant role in enhancing supply chain resilience in the modern era. Efficient resource use and sustainable practices can reduce environmental impact and mitigate supply chain risks (Taticchi et al. 2015). Know-hows such as real-time tracking, predictive analytics, and blockchain boost transparency, enable proactive risk management, and facilitate adaptive decision-making (Ivanov et al. 2019). This study's outcomes underline the critical importance of supply chain resilience techniques for startups operating in dynamic and uncertain business markets. Adopting these various methods, companies can effectively handle risks, mitigate disruptions, and improve their overall sustainability and competitiveness.

One noteworthy observation is the emphasis on quality and compliance processes, which serve as the basis for consistent and reliable operations. Prioritizing quality and compliance from the outset can enable companies to build trust and credibility with stakeholders, as well as establish a robust brand name, which is essential for long-term success. Supply chain flexibility and redundancy was another significant area of concern for companies, which adopted strategies such as supplier diversification, agile operations, and contingency planning. These practices enhance startups' ability to respond to disruptions, mitigate risks related to supply shortages, and adapt to market changes (Gölgeci et al. 2021). In the dynamic and unpredictable conditions that many businesses face, flexibility and redundancy can provide a competitive edge. Notwithstanding, implementing these various practices, many startups reported that their approach to supply chain resilience is often reactive and focused on short-term solutions. Limited financial resources, a lack of specialized supply chain expertise, and a prioritization of product development over supply chain optimization were cited as key barriers to implementing proactive, long-term resilience strategies.

The findings align with previous studies that have emphasized resource constraints and knowledge gaps as significant challenges for startups in adopting comprehensive supply chain risk management practices (Imbiri et al. 2023; Ivanov & Sokolov, 2022). As startups recognize the importance of resilience, their limited capacity often leads to a reactive stance rather than a proactive, strategic approach. These startups also identified the innovation hub environment as a valuable sustenance system, providing access to mentorship, networking opportunities, and shared resources. They highlighted the benefits of peer learning, knowledge sharing, and potential collaborations facilitated by the hub's collaborative environment. Leveraging the hub's ecosystem and capitalizing on the expertise and networks available, startups can enhance their supply chain resilience and sustainability.

Managerial Implications

This study provides valuable insights and actionable commendations for startups, emphasizing the importance of prioritizing supply chain planning and forecasting. These elements are pivotal for mitigating risks and enhancing operational efficiency. Strengthening these capabilities, startups are advised to invest in suitable technologies, pursue mentorship, and collaborate with supply chain experts. Such steps are crucial for developing a robust foundation in supply chain management.

Innovation hubs play a crucial role in facilitating supply chain resilience by offering targeted programs, workshops, and networking opportunities. These initiatives focus on connecting startups with industry partners and subject matter experts, fostering knowledge transfer and the adoption of best practices. This collaborative environment helps startups implement effective supply chain strategies and adapt to changing market demands.

Policymakers and government agencies can also contribute by providing support and incentives for startups to adopt sustainable and resilient supply chain practices. Options might include funding for technological upgrades, training programs, or tax incentives for businesses that implement sustainability and resilience initiatives. Furthermore, startups should adopt a proactive approach to supply chain management by integrating risk assessment and mitigation strategies from the outset. Utilizing tools like Failure Mode and Effect Analysis (FMEA) and Analytical Hierarchy Process (AHP) can help identify potential vulnerabilities and prioritize continuous improvement efforts, ensuring long-term success in a competitive business landscape.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study established a comprehensive framework for evaluating sustainable supply chain risks and resilience in startups within innovation hubs. The research revealed that while these startups have implemented various resilience practices focusing on quality, flexibility, innovation, sustainability, collaboration, and digital transformation, their planning processes remain particularly vulnerable to disruptions. In contrast, delivery and return processes demonstrated lower risk levels. These findings underscore the critical importance of robust planning and forecasting capabilities for startups aiming to effectively mitigate supply chain disruptions.

The study's unique contribution lies in its adaptation of established supply chain management tools to the specific needs of startups, bridging the gap between theoretical models and practical realities faced by emerging businesses. This work is especially timely given the increasing frequency and severity of global supply chain disruptions, offering actionable strategies for startups to enhance their resilience.

Future research should focus on developing specialized risk assessment tools for various startup sectors and growth stages, as well as conducting longitudinal studies to examine the long-term impact of implemented resilience strategies on startup success rates. These efforts would provide valuable insights for both entrepreneurs and policymakers, contributing to the overall robustness of emerging innovation ecosystems.

Recommendations

As this research concludes, startups must establish a comprehensive Enterprise Risk Management framework aligned with industry standards to address all identified risk categories. This approach should promote cross-functional collaboration and coordination of mitigation strategies. Building a risk-aware culture through knowledge sharing, training programs, and continuous improvement initiatives is crucial, as is leveraging the innovation hub ecosystem for knowledge transfer and capacity building in supply chain planning and forecasting. Investing in digital technologies and data-driven solutions will enhance supply chain visibility and decision-making capabilities. Startups should embrace predictive analytics, IoT, and cloud-based platforms to proactively identify and mitigate risks. Fostering strategic partnerships within the supply chain ecosystem is essential for promoting information sharing and collective risk mitigation efforts.

Regular review and refinement of risk management strategies through thorough assessments and monitoring of emerging threats will ensure practices remain relevant and effective. By adopting these recommendations, startups can strengthen their risk management capabilities, foster resilient supply chains, and better navigate the complexities of the modern business landscape while maintaining sustainable and socially responsible practices.

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