Science and Engineering Connect, ISSN 3027-7914 (Online)
Vol. 48 No. 4 pp. 346-369 (2025)

Research Article

# Navigating the Transition to Industry 5.0: Risk and Resilience in Technology Startups

**Nattida Tachaboon***
Faculty of Engineering, Chiang Mai University,
Chiang Mai, Thailand
** Corresponding author E-mail: nattida.t@cmu.ac.th*

Received 2 October 2025; Revised 24 November 2025; Accepted 17 December 2025

## Abstract

**Background and Objectives:** The rapid advancement of digital technologies has driven Industry 4.0, yet emerging research emphasizes a shift toward Industry 5.0, which prioritizes human-centric, sustainable, and resilient innovation. Despite the growing importance of this transition, there is limited understanding of how early-stage technology startups manage risks, while aligning with these Industry 5.0 principles, particularly in emerging economies. The present study aimed to examine how Thai technology startups perceive and navigate risks associated with product development, market adoption, and ecosystem dependencies in the context of Industry 5.0.

**Methodology:** A qualitative multiple-case study design was employed to explore in depth the issues. Seven early-stage technology startups across diverse sectors, including education, healthcare, construction, and alternative medicine, were purposively selected to ensure variation in digital platforms and technology-based products. Semi-structured interviews were conducted with founders or co-founders, focusing on entrepreneurial motivations, business development processes, perceived risks, adaptation strategies, and ecosystem support. The interview data were analyzed using thematic coding, which involved initial coding to identify recurring challenges and risk factors, axial coding to group codes into broader themes, and interpretive analysis to align findings with the emerging Industry 5.0 framework. Themes were validated through cross-checking by multiple researchers and iterative comparison across cases.

**Main Results:** The findings reveal that startups integrate human-centric design, sustainability-oriented innovation, and resilience-building strategies to navigate uncertainty, while simul-

taneously confronting technology and ecosystem-related risks. Human-centric approaches allow startups to align their offerings with real user needs, often informed by the founders' personal experiences and iterative feedback from target users. Sustainability considerations, including social and economic dimensions, contribute to long-term viability by supporting small businesses, promoting equitable access, and addressing societal challenges. Resilience mechanisms, such as pivoting, minimum viable product testing, and learning from failure, enhance startups' adaptive capacity and ability to respond to environmental shocks. Technology-related risks, particularly the recruitment and management of skilled technical talent, along with limitations in funding and mentorship, are identified as critical ecosystem vulnerabilities. Access to incubator support, structured mentorship, and institutional resources play a central role in mitigating these risks and enabling startup survival.

**Conclusions:** Industry 5.0 provides a comprehensive framework for understanding startup risk management that extends beyond purely technical and financial dimensions. The study highlights the importance of integrating human-centricity, sustainability, and resilience in entrepreneurial practice, while also emphasizing the role of ecosystem support in emerging economies.

**Practical Application:** The insights offer practical implications for entrepreneurs, incubators, and policymakers seeking to foster sustainable and resilient startup ecosystems, suggesting that targeted support mechanisms, in combination with iterative and adaptive innovation strategies, can enhance both startup performance and societal impact.

**Keywords:** Technology Startups, Industry 5.0, Risk Management, Human-centric Innovation, Resilience

## Introduction

Technology startups are increasingly recognized as central actors in shaping national innovation systems, driving economic growth, and addressing emerging societal challenges. Their capacity to innovate is not developed in isolation but is closely tied to the wider entrepreneurial ecosystem in which they operate [1]. In Thailand, the startup ecosystem has expanded rapidly over the past decade, supported by government initiatives and university-based programs. Yet, many early-stage ventures continue to face significant risks that hinder their survival and growth. As highlighted by Piyatamrong and Guile [2], Thailand's

innovation system suffers from structural weaknesses: most firms remain dependent on imported technologies, while government innovation policies often fail to effectively stimulate technological upgrading. In this context, startups are positioned as potential agents of transformation, but they face ecosystem constraints including financing gaps, regulatory uncertainty, and limited absorptive capacity.

Universities play an especially important role in this landscape. Beyond their traditional function as knowledge producers, universities increasingly act as anchors of entrepreneurial ecosystems, supporting new ventures through incubation, mentorship, and access to networks. Evidence shows that university–startup collaborations can significantly reduce early-stage risks by providing access to research infrastructure, technical expertise, and market validation opportunities, while also contributing to the sustainability of innovation ecosystems [3]. In Thailand, university-affiliated incubation programs such as those at Chiang Mai University have emerged as vital intermediaries that strengthen the survival and resilience of technology-driven startups.

The global transition from Industry 4.0 to Industry 5.0 adds further complexity to the entrepreneurial landscape. While Industry 4.0 emphasized automation, digitalization, and efficiency through advanced technologies, it also created significant management challenges for small and medium-sized enterprises, including difficulties in resource allocation, workforce adaptation, and technological integration [4]. Industry 5.0, by contrast, introduces a more human-centric and sustainable vision of technological progress, emphasizing adaptability, resilience, and social well-being alongside economic competitiveness [5]. This shift implies that startups are not only expected to compete on technological capability but also to integrate social and environmental considerations into their business models. These changing expectations fundamentally reshape the nature of entrepreneurial risk and demand new approaches to risk management.

Recent scholarship underscores that digital transformation is both a technological and socio-organizational challenge. In Northern Thailand, for example, small and medium-sized enterprises adopting artificial intelligence face barriers such as financial constraints, workforce skill shortages, and data quality issues, but are enabled by leadership capacity and process maturity [6]. At the organizational level, digital transformation is often constrained by the lack of shared language and knowledge practices across diverse teams, underscoring the importance of human and communicative dimensions [7]. These findings reinforce the

argument that entrepreneurial risk cannot be understood solely through financial or operational perspectives but must also account for ecosystem dependencies, human-centered value creation, and the broader transformation toward sustainability.

Despite the growing relevance of these issues, research on startup risk management in emerging economies remains limited. Existing studies rarely integrate Industry 5.0 principles into their analysis, and even fewer examine how risks differ between digital platform and product-based ventures. Moreover, the Thai context remains underrepresented in global discussions, despite its rapidly evolving innovation policies and expanding university incubation infrastructure.

To address these gaps, the present study was guided by the following research questions:

**RQ1:** What types of risks emerge for early-stage technology startups in Thailand in the context of Industry 5.0?

**RQ2:** How do risk characteristics differ between digital platform startups and product-based startups within a university incubation program?

To answer research question, the present study investigated how technology-driven startups in Thailand perceive and address risks during their early development. Drawing on seven case studies of startups supported by the Chiang Mai University incubation program, the research examined the challenges encountered by ventures across both digital platform and product-based domains. By analyzing these cases through the lens of Industry 5.0, the study identified distinct patterns of risk related to human-centric innovation, sustainability-oriented practices, resilience, and ecosystem dependencies.

The present study contributes to the literature in three ways. First, it extends understanding of entrepreneurial risk management in emerging economies by highlighting the specific conditions of Thai technology startups. Second, it introduces Industry 5.0 as a novel framework for analyzing startup risk, thereby moving beyond conventional financial or operational perspectives. Third, it offers practical insights for policymakers, incubators, and entrepreneurs on strategies to mitigate risks and strengthen resilience during the transition toward Industry 5.0.

## Literature Review

### Entrepreneurial Risk in Technology Startups

Technology startups are widely recognized as engines of innovation and growth but

face disproportionately high risks compared to established firms. These risks stem from market, financial, technological, and organizational uncertainties. For instance, startups often confront the "liability of newness" [8], where lack of reputation, resources, and established routines make survival difficult. Market risks involve uncertainty about customer needs, adoption rates, and timing of entry [9]. Financial risks relate to capital scarcity, dependence on external funding, and limited cash flow [10]. Technological risks include challenges of developing scalable solutions, intellectual property protection, and keeping pace with rapid technological changes [11]. Organizational risks often emerge from inexperienced teams, skill mismatches, and conflicts among co-founders [12].

In the context of emerging economies, these risks are further amplified by institutional voids, weak legal frameworks, underdeveloped financial markets, and limited entrepreneurial support structures [13]. In Thailand, structural weaknesses in firm-level technological upgrading and fragmented innovation policies exacerbate these challenges, reinforcing systemic barriers to entrepreneurial success [2].

The entrepreneurial ecosystem itself can be both a source of support and additional risk. Startups embedded in well-functioning ecosystems benefit from access to knowledge, funding, and mentoring, while firms in weaker ecosystems face heightened exposure to failures [1]. University–startup collaborations have emerged as critical mechanisms for mitigating early-stage risks, providing technical expertise, infrastructure, and mentorship to help startups navigate uncertainties [3]. However, dependence on such institutional support can also introduce new vulnerabilities if resources are inconsistent or misaligned with firm needs. For instance, Opassuwan and Mongkolkittaveepol [14] show that in Thailand's manufacturing sector, collaborations with universities or competitors often fail to enhance innovation performance, largely due to weak appropriability mechanisms and underdeveloped linkages. Complementing this, Phongthiya et al. [15] demonstrate that science parks acting as innovation intermediaries can strengthen startups' absorptive capacities, build relational trust, and reduce coordination risks. Together, these findings highlight that while institutional support structures are vital in emerging economies, their impact is highly contingent on context, and they can both mitigate and amplify entrepreneurial risks depending on how they are designed and enacted.

The adoption of advanced technologies introduces additional layers of risk. SMEs in Thailand face barriers to AI adoption including financial constraints, workforce skill shortages, and challenges in process alignment, while successful adoption is facilitated by strong

leadership, organizational readiness, and technological capabilities [6]. Moreover, digital transformation requires more than technological infrastructure; effective knowledge management and shared understanding across teams are crucial to reduce operational and organizational risk [7]. At the same time, technological integration in SMEs and startups is constrained by management practices, workforce readiness, and organizational flexibility [4].

Therefore, examining risks in technology startups requires sensitivity not only to firm-level dynamics but also to broader ecosystem, institutional, and technological conditions. In emerging economies such as Thailand, these interacting layers of risk underscore the importance of human-centric and ecosystem-aware strategies for startup resilience and sustainable growth.

## Industry 4.0 and Startup Challenges

Industry 4.0 refers to the fourth industrial revolution, characterized by the integration of cyber-physical systems, Internet of Things (IoT), big data, and advanced automation. These technologies create opportunities for startups to disrupt traditional industries and build innovative products and services. Startups can leverage agility to experiment with digital business models, platform-based ecosystems, and customer-centric innovations [1].

However, Industry 4.0 also imposes new challenges and risks. First, the need for highly specialized technical knowledge increases dependence on scarce talent [4]. Second, startups must integrate advanced technologies into existing industry structures, which may be incompatible or resistant to change [16]. Third, the rapid pace of digital transformation generates intense competition, requiring startups to scale faster than traditional firms [17]. Finally, resource constraints limit their ability to invest in expensive infrastructure or long R&D cycles, creating a paradox of high ambition but limited capacity.

In emerging economies, Industry 4.0 risks are compounded by limited digital infrastructure, lower absorptive capacity of SMEs, and fragmented support systems. Startups often depend heavily on incubators, accelerators, and university-based programs to fill capability gaps, which makes the quality of ecosystem support a decisive factor in their survival.

### Emerging Industry 5.0 Framework: Human-Centric, Sustainable, Resilient

Industry 5.0, introduced by the European Commission, represents a paradigm shift beyond efficiency-driven digitalization [5]. It emphasizes human-centricity, sustainability, and resilience as guiding principles for innovation.

- **Human-Centricity:** Technology should empower humans rather than replace them. The focus is on worker well-being, inclusiveness, and designing technology that supports human decision-making [18]. In startups, this translates into addressing real social pain points and designing user-centered solutions.
- **Sustainability:** Beyond profit, startups are expected to consider environmental and social dimensions of innovation [3]. This aligns with global sustainability agendas such as the UN SDGs, where innovation is framed as a driver of long-term societal value creation.
- **Resilience:** Startups must prepare for shocks [19]. Resilience is not only about recovery but also about building adaptive capacity and learning through iteration [20].

While Industry 5.0 has gained policy attention, empirical research remains limited. Existing studies tend to emphasize manufacturing contexts and conceptual frameworks rather than startup-level analysis. Applying the Industry 5.0 lens to startups therefore offers an opportunity to enrich both theory and practice.

## Research Gap

Although extensive research addresses entrepreneurial risks under Industry 4.0, the transition toward Industry 5.0 remains underexplored, especially for startups in emerging economies. Most existing studies are conceptual or policy-oriented, focusing on large firms and manufacturing sectors in developed countries. There is limited empirical work examining how early-stage startups interpret and mitigate risks while incorporating human-centric, sustainable, and resilient approaches.

Thailand provides a particularly relevant context for such investigation. While the Thai government has promoted initiatives such as Thailand 4.0 [21] to encourage digital transformation, startups continue to face funding shortages, skill gaps, and ecosystem weaknesses. Research that integrates the Industry 5.0 framework with empirical insights from Thai startups can therefore fill a significant gap by highlighting how risks are experienced and addressed in a developing economy context.

This gap requires methodological approaches that capture nuance, context, and human experiences. A qualitative multiple case study design is therefore appropriate, enabling in-depth exploration of founders' perceptions, decision-making, and lived experiences, elements that quantitative surveys cannot sufficiently reveal.

## Methodology

This study employed a qualitative multiple-case study design [22] to explore how technology startups in Thailand perceive and manage risks during the transition from Industry 4.0 to Industry 5.0. A case study approach was selected because it allows for in-depth investigation of complex, context-dependent phenomena [23], which is appropriate for examining early-stage startups embedded within a developing innovation ecosystem.

## Data Collection

Data were collected through semi-structured interviews with founders or co-founders of seven technology startups that participated in a university-based incubation program in Northern Thailand. The interview protocol covered themes including entrepreneurial motivations, business development processes, perceived risks, adaptation strategies, and ecosystem support. In addition to interviews, supporting materials such as startup pitch decks, incubator reports, and websites were reviewed to triangulate the data.

## Case Selection

The seven cases were selected using purposive sampling to ensure variation across both digital platforms and technology-based products.

**Inclusion criteria:** early-stage technology-driven startups; participants who are founders or co-founders; startups engaged in digital platform or technology-based product development; startups represented diverse application domains including education, healthcare, construction, agriculture, and consumer services; startups incubated the same university-supported program to ensure comparability.

**Exclusion criteria:** non-technology startups; startups outside incubation programs.

## Data Analysis

The interview transcripts were analyzed using thematic coding [24]. The coding process involved three steps:

1) **Initial coding** of transcripts to identify recurring challenges and risk factors.
2) **Axial coding** to group risks into broader categories (e.g., human-centric, sustainability, resilience, technological/ecosystem risks).

3) **Interpretive analysis** to align findings with the Industry 5.0 framework.

To enhance validity, coding was cross-checked by two researchers, and themes were refined through iterative comparison across cases.

## Case Overview

Table 1 provides an overview of the seven startups included in this study.

**Table 1** Overview of the Studied Cases

| Case | Type | Sector/ Application | Description |
|---|---|---|---|
| **Case A: Vocational Job Platform** | Platform | Education / Employment | Connects vocational students to part-time jobs aligned with their skills. |
| **Case B: Craft Learning & Marketplace Platform** | Platform | Creative Economy / Crafting | Online platform for craft courses and marketplace, pivoted from an earlier mental health tourism idea. |
| **Case C: Consumer Testing Platform** | Platform | Innovation Support / Market Validation | Provides sensory testing platform for product prototypes with target customers. |
| **Case D: Construction Contractor Platform** | Platform | Construction / Housing | Connects homeowners with reliable contractors to reduce fraud in renovation projects. |
| **Case E: Healthcare Appointment Platform** | Platform | Healthcare / Services | Appointment booking and management system for clinics and treatment shops. |
| **Case F: Livestock Wound Care Product** | Product | Agriculture / Animal Health | Medical product for healing livestock wounds, refined based on clinic feedback. |
| **Case G: Nutraceutical Supplement** | Product | Health / Alternative Medicine | Nutraceutical supplement for cholesterol reduction as alternative to conventional drugs. |

## Finding

The analysis of seven early-stage technology startups reveals distinct patterns in how entrepreneurs perceive and address risks, aligning closely with the emerging principles of Industry 5.0, as summarized in Table 2. The cases illustrate how human-centric values, sustainability considerations, and resilience-building strategies are integrated into startup practices, while also highlighting vulnerabilities in technology readiness and ecosystem support.

**Table 2** Summary of Themes, Codes, and Observed Risks in Technology Startups

| Theme | Codes / Sub-Themes | Illustrative Cases | Observed Risks |
|---|---|---|---|
| **Human-Centric** | Problem Identification; Product Design; User-Centered Solutions | Case A, Case C, Case D, Case E, Case F, Case G | Misalignment with user needs; low adoption; trust issues |
| **Sustainability** | Social Sustainability; Economic Sustainability | Case A, Case B, Case C, Case D, Case E | Market adoption uncertainty; scalability challenges; balancing social and financial goals |
| **Resilience** | Pivoting & Adaptation; Iterative Development & MVPs; Learning from Failure | Case A, Case B, Case D, Case E | Vulnerability to external shocks; over-reliance on single clients; over-investment in untested features |
| **Technology & Ecosystem** | Technology Risk; Ecosystem Support & Gaps | Case A, Case B, Case D, Case E | Scarce technical talent; limited financial resources; partial ecosystem support |

## Human-Centric Risk and Value Creation

All cases exhibited a strong human-centric orientation, prioritizing real-world human needs in product and service development.

- **Problem Identification:** Startups were founded to solve deeply understood human challenges. Case D (Construction Contractor Platform) was initiated by a founder who personally experienced construction fraud and sought to prevent others from facing

similar financial and emotional harm. The personal nature of the founding motivation is evident, as the founder recounted: "*Going back to when I was cheated, I created a Facebook page called 'Space Story' and intentionally wrote content that said I was cheated by this contractor and how it happened*". The founder also noted that he "*fell victim to a small contractor who scammed him because he was not familiar with the tricks used by small contractors*". Case E (Healthcare Appointment Platform) emerged from inefficiencies observed in the founder's spouse's clinic, prompting a system to improve staff workflow and patient experience. The founder explained the origin: "*My wife is dentist. I am engineer that is why I like to solve the problems. This problem doesn't just happen; however, I have always seen it happens at every clinic that my wife works*". Case A (Vocational Job Platform) aimed to provide relevant employment opportunities for vocational students who otherwise struggled to find suitable part-time work. Market research revealed the extent of the problem: "*We found that around 80% of them do part-time jobs; however, the jobs were not related to what they study*". This struggle was often despite their strong motivation to gain relevant experience, as exemplified by a student who told them: "he still wants to work at the garage because he wants to improve his skill".

- **Product Design:** User experience was a key priority. Case C (Consumer Testing Platform) focused entirely on understanding consumer sensory preferences to inform prototype development. The core philosophy driving their service design highlighted that consumer demand trumps formulation: "*No matter what the recipe is, the most important thing is to ask the consumers if they want to pay for it*". Case G (Nutraceutical Supplement) designed solutions around patient health needs, aiming to provide alternatives with fewer side effects than conventional drugs. The product's rationale was built upon the observation that patients were actively seeking safer alternatives to standard treatments: "*Hospital treatments often use conventional methods, such as Statin drugs, but some patients dislike the long-term use of chemicals due to side effects, leading them to consider alternative medicine or nutraceuticals – the use of food as medicine – as a safer and side effect-free option*".

- **User-Centered Solutions:** Iterative feedback informed product refinement. Case F (Livestock Wound Care Product) adjusted formulations based on veterinarian feedback regarding absorption and application methods, ensuring real-world effectiveness. This commitment to field effectiveness was demonstrated by the response to feedback from users: "*a clinic that said the cream doesn't absorb well into wounds and is not suitable for wounds that have a lot of discharge*". This feedback was used to further develop the product and add necessary notes about its appropriate use. Case A tailored its platform to align students' skills with suitable part-time opportunities rather than generic job listings. This detail-oriented approach allows students to gain highly relevant experience: "*Automotive job can be many things, such as painting, suspension system. This can solve problems on students get the job that they are not expert on*".

**Observed Risks:** The primary risks in this domain included user adoption, trust, and misalignment with target needs.

**Mitigation Strategies:** Startups leveraged co-creation, iterative testing, and partnerships with schools or professional networks to strengthen user alignment and trust.

## Sustainability-Oriented Innovation Risks

Several startups incorporated social and economic sustainability into their business models.

- **Social Sustainability:** Case A promoted equitable educational and employment opportunities for students. The founders were driven by the belief that "*education is the starting point of everything, starting point of children opportunity*" and that they needed to do something for vocational students, noting that "*if we don't do something for college student, no one does it*". Case B (Craft Learning & Marketplace Platform) encouraged cultural preservation and provided avenues for artisans, including older adults, to earn income. The platform was created recognizing that "*Some elders want to teach and sell crafting products online, and they want platform that easy for them to use*". Case D contributed to a transparent and trustworthy construction sector, fostering social trust. The founder, having been a victim of fraud, focused the solution on preventing others from facing similar problems. The platform's revenue model includes a future payment system

where "the homeowner pays money into the platform first, and then the platform will hold the money for the contractor to build. Once the task is completed, the homeowner will come and approve it".

- **Economic Sustainability:** Startups supported small business growth and financial stability. Case E improved clinic revenue and operational efficiency. The platform aims to support business owners by helping them manage capacity and reduce errors: "*it aims to support the business owner to increase the revenue, reduce the cost, and reduce the human error*". Case C helped SMEs de-risk product launches by ensuring consumer demand before mass production. This service gives customers confidence to proceed to scale-up, as the founders noted that clients agree "because they could know the possibility of the product before rum the mass production". Case D offered tiered service packages to make solutions accessible for homeowners with varying budgets. The service offers different packages for customers depending on their needs, such as managing and supervising construction work for those who already have a design.

**Observed Risks:** Market adoption uncertainty and scalability challenges, especially for initiatives tied to social or cultural value, posed significant challenges.

**Mitigation Strategies:** Entrepreneurs pivoted business models, conducted pilot testing, and strategically engaged target communities to validate and scale offerings.

### Resilience and Adaptive Risk

Resilience emerged as a cross-cutting theme across all cases, reflecting the ability to adapt, learn, and recover from disruptions.

- **Pivoting and Adaptation:** Case B exemplified resilience by pivoting from a mental health tourism business to an online crafting platform following COVID-19 disruptions. The founders explicitly stated the necessity of the pivot due to external crisis: "*In 2019, we started the mental health tour company. In the tour, there was the crafting activity. But because of the Covid, we could not arrange the tour. So, we decided to focus on crafting activity, establish the platform for crafting*".
- **Iterative Development and MVPs:** Lean development approaches enabled startups to manage uncertainty. Case D initially operated using simple digital tools before investing in a full platform. Their initial solution was entirely manual: "*Instead of*

*being our platform, we used Google forms for customers to sign up, collect data, and let the contractors submit a quote and fill out their profiles"*. This current running version is defined as MVP2, demonstrating structured iterative growth. Case A similarly started with basic functionality to test user engagement. The platform's early stage relied heavily on low-cost, manual processes, as they currently use "*Facebook group as our platform*". They determined that: "*This approach ensured the base was strong before investing heavily in website structure*".

- **Learning from Failure:** Startups iteratively learned from setbacks. Case E devoted a year to developing a feature for one client who eventually opted not to use it, reinforcing the need to balance customization with broader market applicability: "*After I finished, I went back to talk to him, and he said he didn't want to use it. I was so angry that time. I thought that I might give too much value to his comment. This was my mistake*". Case D restarted its platform after realizing initial development strategies were too resource-intensive without clear user validation. The founder admitted a fundamental mistake early on: "*At first, I got lost in the app, which was not an MVP. It skipped MVP and went straight to the product, which is marketing, even though the business model is not clear yet*".

**Observed Risks:** Exposure to external shocks, over-reliance on single clients, and over-investment in untested features.

**Mitigation Strategies:** Lean experimentation, staged development, market diversification, and continuous learning allowed startups to enhance adaptive capacity.

### Technology and Ecosystem Risks

Technology and ecosystem-related risks were critical across most cases, particularly for non-technical founding teams.

- **Technology:** Recruiting and managing technical talent posed ongoing challenges. Case B experienced delays when contracted developers proposed mid-project changes. Since the co-founders were marketing experts and had no internal developer, they faced problems when relying on external developers: "*The developer team had used one language. One day, one of the developers lift the team, and the others said they were not get used to that language and they wanted to change another one*". Case E struggled to find systematic developers.

The founder identified the challenge as being "*about finding good developer*". Case D faced slow development due to part-time technical resources. This reality led the founder to seek senior technical expertise: "*I think I might need a CTO*".

- **Funding:** For many startups, funding was a primary obstacle, particularly for Case A. The founder explicitly stated: "*The main problem now is the funding. That's why we are trying to save all costs*". They recognized that funding could accelerate growth: "*If we had more funding, everything might be smoother*".
- **Institutional Support:** While institutional support was valuable, founders noted needs that required deeper, more continuous engagement. Case A noted that "*coaching from programs was only periodic, once a month*". Case B wished for more frequent advice from mentors: "*We want 10 big brothers. Currently, we talk to senior startup once a month, which is not enough. Our business changes every week*". They found advice from senior, experienced startups particularly valuable, contrasting it with theoretical guidance. Case D noted the difficulty in securing experienced technical leaders. Case D explicitly stated that "*Incubation can assist with matching CEOs and CTOs*," recognizing that technical individuals often hesitate to leave comfortable jobs for a startup.

**Observed Risks:** Dependence on scarce technical talent, limited financial resources, and partial ecosystem support.

**Mitigation Strategies:** Leveraging incubator networks, staged development, mentorship programs, and incremental product deployment helped mitigate technology and ecosystem vulnerabilities.

## Discussion

This study explored how early-stage technology startups in Thailand perceive and manage risks, analyzed through the lens of Industry 5.0. The findings provide insights into how startups integrate human-centric values, sustainability, and resilience while navigating technological and ecosystem challenges. Figure 1 illustrates how human-centricity, sustainability-oriented innovation, resilience, and ecosystem dependencies shape the risk profiles of early-stage technology startups in Thailand. The Industry 5.0 perspective positions these dimensions as interconnected rather than separate risk categories.

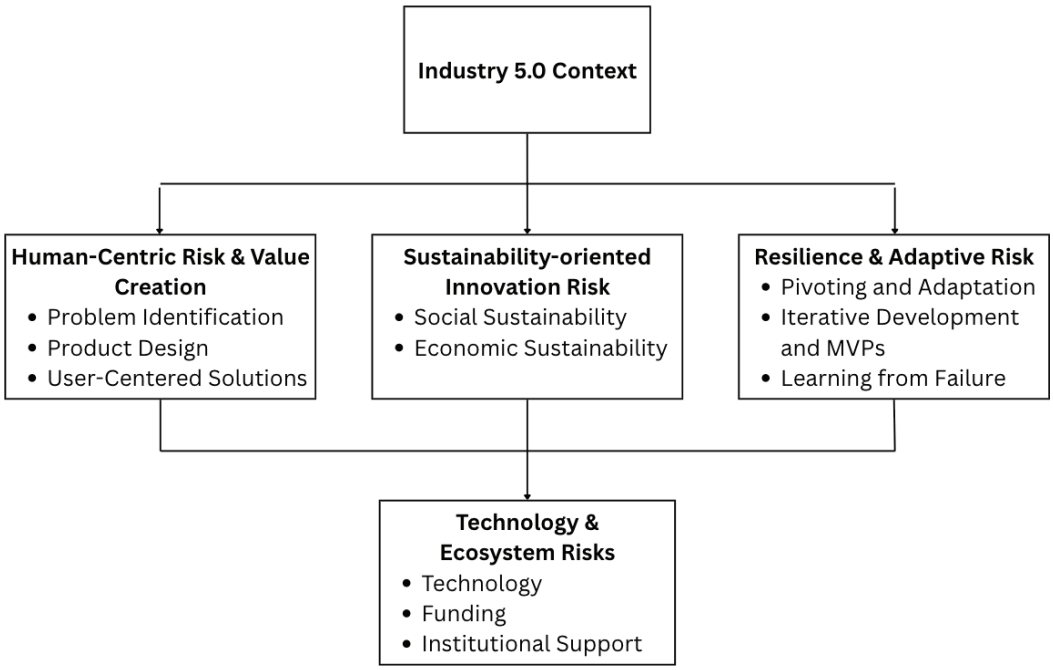


**Figure 1** Conceptual Framework of Startup Risk in the Context of Industry 5.0

Below, we discuss these findings in relation to prior research and the emerging Industry 5.0 framework.

## Human-Centric Risk and Innovation

Our findings show that startups prioritize human needs and experiences, consistent with Industry 5.0's emphasis on human-centricity [18]. Founders often initiated ventures based on personal experiences with a societal or individual problem (e.g., Case D, Case E), aligning with prior research on entrepreneurial opportunity recognition driven by lived experience.

Globally, human-centric innovation has been highlighted as a defining element of next-generation entrepreneurship, especially in contexts where innovation is intended to generate social or community-level value [3]. The emphasis placed by Thai startups on co-creation and iterative user testing resonates with studies in Europe demonstrating that human-centric design reduces market uncertainty and supports early customer trust. Compared to Industry 4.0 approaches, which focus primarily on efficiency and digital automation [4], these startups demonstrate a broader risk perspective encompassing user trust, ethical considerations, and social value creation.

### Sustainability-Oriented Innovation Risk

The analysis revealed that startups actively incorporate social and economic sustainability, supporting both societal needs and small business ecosystems. Case A (Vocational

Job Platform) and Case B (Craft Platform) exemplify ventures that balance social impact with economic viability.

These findings extend prior research that links sustainability with long-term competitiveness [3]. In the context of emerging economies, startups often face a dual challenge: addressing social value creation while ensuring financial survival. Unlike Industry 4.0 frameworks, which largely focus on technological productivity and efficiency, Industry 5.0 broadens the lens to societal and environmental outcomes, highlighting new dimensions of risk such as market adoption for socially-oriented products.

## Resilience and Adaptive Risk

Resilience emerged as a key mechanism for mitigating uncertainty. The study showed that startups employ pivoting, MVP strategies, and learning from failure to adapt to environmental shocks (e.g., Case B pivoting after COVID-19).

This supports research on dynamic capabilities in startups, emphasizing flexibility, iterative learning, and adaptive strategy [19, 20]. Industry 5.0's focus on resilience is particularly relevant, highlighting that startups must not only survive shocks but also develop adaptive capacity to thrive in rapidly changing technological and societal contexts.

## Technology and Ecosystem Risks

Technology risk and ecosystem dependencies were significant across the cases, articularly for startups lacking in-house technical expertise. Case D and Case E illustrate challenges with developer recruitment, project delays, and reliance on external ecosystem actors. These findings align with prior studies on Industry 4.0 challenges, where technology adoption requires specialized skills and ecosystem support [16, 17].

However, the Industry 5.0 perspective emphasizes that risk is not solely technical: startups must also manage social, human, and sustainability dimensions within the ecosystem. Gaps in funding, mentorship, and technical guidance can threaten both innovation and resilience. In this context, the effectiveness of external collaborations becomes critical. Prior research found that firms in Thailand did not always benefit from collaborations with universities and other partners due to weak linkages and limited knowledge transfer [14]. This suggests that startups' dependence on ecosystem actors can introduce additional risks, particularly when the quality or alignment of support is insufficient to enhance technological capabilities or innovation performance.

## Platform vs. Product Differences

Technology risk and ecosystem dependencies were significant across all cases, but the nature of these risks differed sharply between platform ventures and product-based ventures.

Platform ventures depended heavily on the broader ecosystem for market access, software development, and integration support. Several founders lacked in-house technical expertise and relied on outsourced developers. This created additional risks: when outsourced teams rotated or preferred different programming languages, platforms faced delays, code inconsistencies, and rising technical debt. These ecosystem dependencies amplified vulnerabilities, when actors such as developers, channel partners, or marketplace operators became unavailable, the platform's progress stalled.

In contrast, product-based ventures (typically led by university researchers) possessed strong internal technological capabilities, reducing the risk of core R&D failure. However, their vulnerabilities emerged in other areas: customer identification, market access, and commercial integration.

These findings resonate with global studies on Industry 4.0 adoption, where the availability of specialized talent, robust supplier networks, and integrator support is critical for technology-intensive innovation. Yet, aligning with the Industry 5.0 perspective, the cases show that risk is not merely technical. Startups must also navigate human, organizational, and socio-ecosystem dimensions, including gaps in funding, mentorship, and commercialization guidance. Without coordinated ecosystem support, both platform and product ventures experience reduced resilience and stalled innovation.

### Shift from Industry 4.0 to Industry 5.0

Table 3 highlights the shift from a technology-dominant approach (Industry 4.0) toward an integrated perspective where social, ecosystem, and resilience factors become essential to innovation and survival. This comparison strengthens the theoretical contribution by showing how Industry 5.0 redefines the nature of risk.

**Table 3** Comparison of Industry 4.0 and Industry 5.0 Perspectives on Innovation and Risk Management

| Dimension | Industry 4.0 | Industry 5.0 | Implications for Startup Risk |
|---|---|---|---|
| Core focus | Automation, efficiency | Human-centric, collaborative | New risks related to user needs, human factors |
| Innovation logic | Tech-driven | Value-driven (social + environmental) | Broader innovation uncertainties |
| Skills requirements | Technical, digital | Hybrid social–technical | Higher dependency on multidisciplinary teams |
| Resilience | Operational continuity | Adaptive capacity, systemic resilience | Shocks (pandemic, crises) require flexible pivot strategies |
| Ecosystem role | Supply chain integration | Societal ecosystem integration | Importance of incubation, collaboration, and knowledge transfer |

## Answering Research Questions

Overall, the findings suggest that Industry 5.0 provides a useful framework for understanding startup risk, expanding traditional perspectives beyond technology and finance to incorporate human-centricity, sustainability, and resilience. By examining Thai university-incubated startups, this study contributes empirical evidence from a region underrepresented in global entrepreneurship research and demonstrates how Industry 5.0 principles unfold within an emerging-economy innovation ecosystem. This study addressed two research questions:

***RQ1:*** *What types of risks emerge for early-stage technology startups in Thailand in the context of Industry 5.0?*

In the context of Industry 5.0, early-stage technology startups in Thailand face a complex set of risks that can be segmented into three internal capability-related categories derived from the Industry 5.0 principles and one crucial external enabling category. The internal risks include the **Human-Centric Risk & Value Creation**, which is the fundamental danger of market misalignment where founders fail at genuine problem identification or create solutions that lack sufficient user-centered value. Next is the **Sustainability-oriented Innovation Risk**, which relates to the dual challenge of achieving long-term competitiveness by balancing social and economic viability. This risk involves market adoption uncertainty for socially-oriented

products and the failure to fully integrate societal benefits, such as equitable access or support for small businesses. The third internal risk is the **Resilience & Adaptive Risk**, defined as the vulnerability to external shocks and the operational risk of over-investment in untested features. Mitigating this risk requires startups to develop dynamic capabilities through consistent pivoting, the use of Minimum Viable Products (MVPs), and institutionalized learning from failure.

These internal operational risks are fundamentally underpinned by the overarching external **Technology & Ecosystem Risks**. This systemic challenge is rooted in the high dependency on external ecosystem actors, particularly concerning specialized skills and resources. Key risks here include technology dependence, where startups struggle with developer recruitment and face project delays due to lacking in-house technical expertise. Furthermore, there is a risk associated with ecosystem gaps in providing quality funding, structured mentorship, and technical guidance. As the discussion highlights, reliance on these external actors can introduce secondary risks, such as those related to weak linkages and limited knowledge transfer.

***RQ2:*** *How do risk characteristics differ between digital platform startups and product-based startups within a university incubation program?*

The findings reveal distinct risk profiles. **Platform ventures** face higher technology and ecosystem risk, including developer turnover, codebase inconsistencies, reliance on outsourced developers, and dependence on external actors for both technology and market access. **Product ventures** face lower R&D uncertainty but higher commercialization and insufficient customer discovery capabilities. These differences indicate that risk is shaped not only by technology maturity but also by business model architecture and the structure of ecosystem interactions.

## Conclusion

This study examined how early-stage technology startups in Thailand perceive and manage risks, particularly in the context of transitioning from Industry 4.0 to Industry 5.0. Through a multiple-case study approach, the analysis revealed that human-centricity, sustainability, resilience, and ecosystem support are critical dimensions of both risk and innovation in startup practice. Startups consistently prioritize addressing real human problems, often grounded in the founders' personal experiences, which helps reduce misalignment with user needs and enhances adoption. This finding underscores that human-centric design is not

only an ethical and societal imperative but also a strategic mechanism for mitigating market risk.

In addition, the startups demonstrated a strong integration of social and economic sustainability into their business models. Socially-oriented innovations contribute to societal well-being, such as improving educational and employment opportunities for marginalized groups, while economic sustainability ensures financial viability for both the startup and the small businesses they support. This dual focus highlights the importance of balancing social impact with business outcomes, a challenge that becomes particularly salient in emerging economies with nascent innovation ecosystems.

Resilience emerged as a central capability for managing uncertainty and external shocks. Startups employed strategies such as pivoting, iterative development with minimum viable products, and learning from failure to adapt their business models dynamically. These mechanisms allowed startups to withstand market and operational uncertainties and to continuously refine their offerings in response to real-world feedback. Complementing internal capabilities, access to ecosystem support, including incubators, mentorship programs, and funding, proved critical for mitigating technology and operational risks, especially for teams lacking in-house technical expertise. At the same time, gaps in technical guidance and financial support remain key vulnerabilities, highlighting areas where policy and institutional interventions can strengthen startup success.

The findings have both theoretical and practical implications. Conceptually, the study extends the literature on entrepreneurship and innovation by demonstrating that Industry 5.0 provides a useful framework for understanding startup risk beyond traditional technical and financial considerations. Human-centric and sustainable approaches are not only socially valuable but also serve as strategic tools for managing uncertainty. Resilience functions as a dynamic capability that links internal processes with external ecosystem support, emphasizing the interconnectedness of startup risk management. Practically, the study suggests that entrepreneurs can enhance their adaptive capacity by embedding human-centric and sustainability-oriented strategies.

Despite these contributions, the study has limitations. It is based on seven early-stage technology startups in Thailand, which constrains the generalizability of the findings. All startups were drawn from a single university incubation program, meaning the findings may reflect ecosystem-specific dynamics rather than the full diversity of Thai startups. Data were based on self-reported founder interviews, which may introduce recall bias or selective framing.

Future research could expand the sample to include startups from multiple regions in Thailand or across ASEAN to validate cross-context patterns. Longitudinal studies could explore how risk perceptions change over different growth stages. Quantitative modeling may complement the qualitative insights by measuring how human-centricity, resilience, and ecosystem support statistically influence survival and performance in the transition toward Industry 5.0.

## References


1. Autio, E., Nambisan, S., Thomas, L.D. and Wright, M. 2018. Digital affordances, spatial affordances, and the genesis of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal*, 12, 72-95.
2. Intarakumnerd, P. 2019. Thailand's middle-income trap: Firms' technological upgrading and innovation and government policies. *Seoul Journal of Economics*, 32, 107-135.
3. Jirapong, K., Cagarman, K. and von Arnim, L. 2021. Road to sustainability: University–start-up collaboration. *Sustainability*, 13, 6131.
4. Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S. and Barbaray, R. 2018. The industrial management of SMEs in the era of Industry 4.0. *International Journal of Production Research*, 56, 1118-1136.
5. Fukuyama, M. 2018. Society 5.0: Aiming for a new human-centered society. *Japan Spotlight*, 27, 47-50.
6. Boonmee, C., Mangkalakeeree, J. and Jeong, Y. 2025. Towards sustainable digital transformation: AI adoption barriers and enablers among SMEs in Northern Thailand. *Sustainable Futures*, 10, 101169.
7. Piyatamrong, T. and Guile, D. 2024. Cultivating Workplace Innovation: Establishing a Common Technical Language for Knowledge Management in a Digital Transformation Perspective-A UK-Based Global Consulting Firm Case Study. *2024 IEEE International Conference on Technology Management, Operations and Decisions (ICTMOD)*, IEEE, Sharjah, United Arab Emirates. https://doi.org/10.1109/ICTMOD63116.2024.10878215.
8. Stinchcombe, A.L. 2013. Social structure and organizations 1, in Handbook of organizations (RLE: Organizations). Routledge, 142-193.
9. Song, M., Podoynitsyna, K., Van Der Bij, H. and Halman, J.I. 2008. Success factors in new ventures: A meta-analysis. *Journal of Product Innovation Management*, 25, 7-27.

10. Cassar, G. 2004. The financing of business start-ups. *Journal of Business Venturing*, 19, 261-283.
11. Cantamessa, M., Gatteschi, V., Perboli, G. and Rosano, M. 2018. Startups' roads to failure. *Sustainability*, 10, 2346.
12. Klotz, A.C., Hmieleski, K.M., Bradley, B.H. and Busenitz, L.W. 2014. New venture teams: A review of the literature and roadmap for future research. *Journal of Management*, 40, 226-255.
13. Bruton, G.D., Ahlstrom, D. and Obloj, K. 2008. Entrepreneurship in emerging economies: Where are we today and where should the research go in the future. *Entrepreneurship Theory and Practice*, 32, 1-14.
14. Opassuwan, T. and Mongkolkittaveepol, P. 2023. Enhancing a Firm's Innovation Performance: On the Interplay between Internal R&D and External Collaboration. *Proceedings of the 2023 5th International Conference on Management Science and Industrial Engineering*, Chiang Mai, Thailand, 348–352. ACM. https://doi.org/10.1145/3603955.3604286.
15. Phongthiya, T., Malik, K., Niesten, E. and Anantana, T. 2022. Innovation intermediaries for university-industry R&D collaboration: Evidence from science parks in Thailand. *The Journal of Technology Transfer*, 47, 1885-1920.
16. Frank, A.G., Dalenogare, L.S. and Ayala, N.F. 2019. Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, 210, 15-26.
17. Pustovrh, A., Rangus, K. and Drnovšek, M. 2020. The role of open innovation in developing an entrepreneurial support ecosystem. *Technological Forecasting and Social Change*, 152, 119892.
18. Nahavandi, S. 2019. Industry 5.0-A human-centric solution. *Sustainability*, 11, 4371.
19. Williams, T.A., Gruber, D.A., Sutcliffe, K.M., Shepherd, D.A. and Zhao, E.Y. 2017. Organizational response to adversity: Fusing crisis management and resilience research streams. *Academy of Management Annals*, 11, 733-769.
20. Teece, D., Peteraf, M. and Leih, S. 2016. Dynamic capabilities and organizational agility: Risk, uncertainty, and strategy in the innovation economy. *California Management Review*, 58, 13-35.
21. Jones, C., and Pimdee, P. 2017. Innovative ideas: Thailand 4.0 and the fourth industrial revolution. *Asian International Journal of Social Sciences*, 17, 4-35.

22. Yin, R.K. 2018. Case Study Research and Applications (Vol. 6). Sage Publications, California.
23. Eisenhardt, K.M. 1989. Building theories from case study research. *Academy of Management Review*, 14, 532-550.
24. Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77-101.