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Digital Innovation to Overcome Structural Barriers and Sustainability in Tourism Immigrant Entrepreneurship

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Abstract: This study examines how immigrant entrepreneurs in tourism use digital innovations to overcome structural barriers while integrating environmental, socio-cultural, and economic sustainability principles. Existing research treats social, institutional, and market embeddedness as static constraints that immigrant entrepreneurs must navigate. This study draws on mixed embeddedness theory and employs Total Interpretive Structural Modelling-Polarity (TISM-P) to identify seventeen factors and relationships that determine successful digital transformation pathways. The hierarchical model reveals collaborative networks and continuous skills training as independent drivers, while adoption challenges emerge as negative drivers. The study outlines four critical pathways through which immigrant entrepreneurs progress from basic digital knowledge to sustainable, culturally informed business transformation. Critically, the hierarchical relationships suggest that resource scarcity may encourage necessity-driven innovation and adaptive capability development. The study advances theoretical understanding by extending the entrepreneurial ecosystem framework to incorporate technology-facilitated sustainability practices and cultural exchange as a distinctive competitive advantage. Practical implications include recommendations for tourism-specific digital competencies targeting seasonality management and experience co-creation, and culturally diverse metrics for assessing immigrant entrepreneurial contributions to sustainable destination development.

Keywords: immigrant entrepreneurship; digital innovation; sustainable tourism; mixed embeddedness; entrepreneurial resilience; cultural intelligence

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1 Introduction

Immigrant entrepreneurs advance sustainable tourism through cultural heritage and resource-conscious practices. Research on immigrant entrepreneurship and digital innovation has grown substantially, yet their intersection, particularly within sustainable tourism contexts, remains inadequately explored. This research fragmentation poses a critical question: How do immigrant entrepreneurs simultaneously overcome structural barriers and integrate sustainability even when they are resource-constrained and the two strategic options require heavy investment? Sustainability in this context extends beyond environmental preservation to encompass economic resilience and socio-cultural inclusivity. It becomes particularly relevant for immigrant-led tourism enterprises that operate across cultural and institutional boundaries and often employ innovative practices to expand and differentiate themselves despite initial marginalisation (Rahman et al. 2021; Chen 2024).

Mixed Embeddedness Theory (MET) explains immigrant entrepreneurship as the interplay of social, market, and institutional embeddedness. However, the literature posits them as static constraints rather than strategic opportunities that immigrant entrepreneurs can leverage. Adoption of digital technologies challenges this static assumption by allowing for extending collaborative networks beyond geographical location, institutional workarounds, and cultural capital monetisation. This study adds to the MET by highlighting how digital innovation acts as a measure to reconfigure embeddedness as a constraint to resources. Simultaneously, embeddedness conditions also shape the digital tools that become viable. They determine the pace, form, and direction of digitalisation. Furthermore, market practices often determine the tools that are needed and hence adopted. Similarly, social networks also impact the tools and platforms that an entrepreneur can adopt. Thus, embeddedness actively shapes the digital pathways that immigrant entrepreneurs pursue, making the relationship recursive than unidirectional. This study, therefore, conceptualises DI as a mechanism through which embeddedness can shift from a static constraint toward a dynamic capability system.

The existing Dynamic Capabilities framework highlights how businesses sense and seize opportunities that allow them to transform their business operations. However, its applicability is challenged in the case of resource scarcity and institutional exclusion. These two conditions are key characteristics of an immigrant entrepreneur. This study is based on the assumption that structural embeddedness requires collaborative networks that enhance the organisation's dynamic capabilities. This challenges the implicit assumption that dynamic capabilities require resource abundance, revealing alternative developmental pathways for immigrant

entrepreneurs. These pathways often lead to sustainability-oriented innovation, where the process of adapting to constraints becomes a source of long-term environmental and social sustainability. Considering this recursive relationship, we position digital capabilities as both outcomes of embeddedness and mechanisms that transform it. This discussion thus integrates MET and the relationship between MET and dynamic capabilities by showing that sensing and seizing opportunities emerge through continuous interaction with institutional and socio-cultural contexts.

The barriers immigrant entrepreneurs face are well-documented. The barriers can range from financial constraints to cultural differences and legal restrictions. Strategies for overcoming these barriers often involve innovative approaches that make the most of immigrant entrepreneurs' unique strengths and resources (Gurău et al. 2020; Khazaei et al. 2017; Pırnar and Altın 2024). The path to success can be, in many cases, filled with difficulties that may persist across generations (Cukier et al. 2024; Shi and Shi 2022). However, there is limited research on the innovative strategies and leadership approaches used to overcome challenges and gain a competitive edge.

The tourism industry is widely regarded as a critical context where immigrant entrepreneurs leverage entrepreneurship as a path to sustainable self-efficacy. They are found to generate substantial economic benefit and digital innovation diffusion in the industry. However, the tourism industry's inherent embeddedness makes it challenging for them to fully capitalise on their advantages. Moreover, existing research has a limited answer to how immigrant entrepreneur in tourism deploys digital innovation to integrate sustainability in operations and overcome structural embeddedness. Sustainability integration here involves balancing the ecological footprint of tourism operations with community well-being and long-term destination viability. Thus, digital innovation and mixed embeddedness evolve together in a continuous feedback process. Digital infrastructures modify how immigrant entrepreneurs navigate structural barriers, while the surrounding institutional and market landscapes continually reshape the meaning, utility, and adoption of these digital tools. This co-evolution is the foundation argument of the study.

This study addresses this gap by examining digital innovation as not merely a tool for competitive advantage, but rather as a transforming mechanism that helps sense and seize sustainable opportunities and overcome structural barriers. This study precisely targets this knowledge gap by examining how digital innovation enables immigrant tourism entrepreneurs to overcome operational challenges and advance sustainability practices in their host countries. Based on the above discussion, the study seeks to answer the following research question. How do immigrant entrepreneurs in the tourism sector use digital innovation to integrate sustainability and overcome structural barriers in host countries?

2 Theoretical Foundations

2.1 Construct Definitions

In the study, *digital innovation* refers to the specific changes in products, processes, and service delivery enabled by digital technologies with a focus on value creation and distribution. *Digital transformation* shall be understood as a continuous change in the organisation in which digital technologies reshape business models and daily activities. It is broader than innovation, which focuses more on a single activity, and reflects systemic adaptation at the firm level (Valeri and Albattat 2024).

Sustainability in the study refers to the economic, social, and environmental outcomes at the firm level. These related outcomes are considered reinforcing and are studied only in the context of immigrant entrepreneurial firms. Economic sustainability means long-term viability, performance stability, and growth potential of the firm. Social sustainability means outcomes related to stakeholder relationships, community integration, and developing social legitimacy. Environmental sustainability is linked to ecological responsibility and efficient resource usage.

Structural barriers arising from the environment include constraints from institutions, regulations, infrastructure, and resource limitations. These limit the growth opportunities available to immigrant entrepreneurs. *Embeddedness* in the study means the extent to which entrepreneurial actions are shaped by social, institutional, and market relationships in both local and transnational settings. It reshapes the entrepreneur's ability to strengthen themselves by capturing how entrepreneurs access resources, opportunities, and legitimacy through relational structures.

This study integrates mixed embeddedness theory, dynamic capabilities theory, and entrepreneurial ecosystems. Rather than treating these as separate perspectives, the concepts are integrated to provide a coherent analytical framework. MET explains how institutional and structural conditions create both constraints and opportunities for entrepreneurs. Within this study, structural barriers represent the restrictive conditions embedded in the environment. Dynamic capabilities explain how entrepreneurs respond to such barriers through sensing opportunities, seizing them, and reconfiguring resources. In the study, digital transformation is considered a mechanism that supports capacity development and adaptability. These perspectives describe an ecosystem in which resources flow and interactions take place. Environmental conditions, represented by structural barriers, influence entrepreneurial responses. These responses are reflected in the digital transformation-led capacity development, which affects entrepreneurs' position in networks and

institutional matters. Such repositioning ultimately shapes their sustainability positioning.

Within this framework, reconfigurable embeddedness means an entrepreneur's ability to realign their position within social, market, and institutional relationships through digital capabilities. It highlights that embeddedness is not static and can be structurally altered through digitalisation. Reconfigurable embeddedness needs changes in three key areas. First, it alters network configuration by giving access to partners or markets. Second, the entrepreneur may reposition institutional presence by strengthening legitimacy and compliance pathways. Third, it requires resource access and utilisation patterns. The study hypothesises that digital transformation can act as a driver for reconfiguration, while structural barriers shape the direction and extent of such changes.

2.2 Mixed Embeddedness Theory (MET): Evolution and Digital Extensions

Mixed Embeddedness Theory (MET), developed by Kloosterman and Rath (2001), lays the foundation for understanding why and how immigrant entrepreneurs adopt digital technologies to overcome barriers and complexities in a new environment. MET establishes that entrepreneurial success depends on three key factors: institutional embeddedness, social embeddedness, and market embeddedness (Yamamura and Lassalle 2022). Institutional embeddedness comprises regulatory frameworks and policies. It assumes that the organisation and its economic activities are intertwined such that cultural norms, values, and normative contexts influence behaviour within and beyond the organisation. Prior studies have observed that complex regulatory systems, licensing requirements, and bureaucratic procedures often disadvantage new market entrants, emphasising those lacking local institutional knowledge and established advisory networks (Hack-Polay et al. 2020). It is more critical in tourism entrepreneurship where regulations include business registration, environmental compliance, safety standards, and sector-specific licensing requirements. Immigrant entrepreneurs have to meticulously arrange for measures that assist them in overcoming these complexities.

Social embeddedness encompasses networks and cultural resources and highlights how organisations' actions are shaped by social networks and not solely based on economic motives. Past studies confirm that immigrant entrepreneurs have limited access to local business networks and professional associations (David and Terstriep 2025; Evansluong et al. 2024). They also face social exclusion from established business communities, which restricts their partnership opportunities, mentorship, and limits knowledge about local business practices (Azmat 2013).

Additionally, they lack informal information channels, which are key sources of business development information. In tourism entrepreneurship, relationships between value chain partners and stakeholders hold significant value. However, such stakeholders may remain sceptical of new business entrants.

Lastly, market embeddedness comprises market structures and competitiveness and suggests that an organisation's activities are not isolated and are shaped by social structures, relationships, and institutions. Studies establish that limited knowledge about local customer preferences and market positioning severely impacts entrepreneurial success (Davidavičienė and Lolat 2016). Home market approaches may be culturally inappropriate for the host markets, leaving immigrant entrepreneurs to rely on assumptions. In tourism, market knowledge gaps are critical as understanding seasonal variations in demand, diverse customer segments and their needs, and knowledge about destination-specific value propositions are critical when competing against established businesses.

2.3 Dynamic Capabilities and Entrepreneurial Ecosystems

Dynamic Capabilities means "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece et al. 1997). These capabilities assist organisations in leveraging their short-term positions to build long-term, sustainable competitive advantage. Prior studies establish that dynamic capabilities assist organisations in sensing opportunities, seizing resources, and transforming organisational capabilities in response to changing market conditions (Pitelis et al. 2024). Immigrant entrepreneurs continuously handle institutional, market, and social challenges in an unfamiliar environment. Therefore, dynamic capabilities become an important measure to manage challenges and build individual capabilities.

The entrepreneurial ecosystem framework extends this individual-level analysis by examining how external support structures, networks, and institutional arrangements either facilitate or constrain capability development (Bamfo et al. 2023; Stephens et al. 2022). In tourism, the entrepreneurial ecosystem consists of stakeholders, destination management organisations, tourism boards, local business associations, and digital intermediaries. The intersection of ecosystem and dynamic capabilities assists immigrant entrepreneurs in the opportunity recognition and resource mobilisation process (Roundy and Fayard 2019; Valeri 2025). It allows them to reconfigure their strategic positioning in response to structural constraints periodically.

Digitalisation is important in helping immigrant entrepreneurs overcome key challenges, especially to have stronger capabilities and be able to connect easily with

the entrepreneurial ecosystems (Borsano et al. 2024). The use of tools such as Big Data analytics, social media monitoring, and AI business intelligence allows for the simultaneous identification of real-time opportunities in several markets. Besides, some online platforms could facilitate interactions with their customers, suppliers, and funding sources. They could use digital technologies such as cloud computing, automation, and digital workflows to improve productivity, rapidly scale their operations, and adjust business models to respond to dynamic challenges (Valeri 2024).

2.4 Digital Innovation (DI) as Embeddedness Mediator

Having established the theoretical foundations of mixed embeddedness theory and dynamic capabilities within the entrepreneurial ecosystem, this section underscores how digital innovation (DI) acts as a mediator between constraints and entrepreneurial success. Recent scholarship highlights that immigrant entrepreneurs increasingly leverage digital innovation to overcome traditional barriers in host countries (Belrhazi and Azougagh 2024). DI transforms opportunities into sustained competitive advantage. A systematic analysis of institutional, social, and market embeddedness dimensions demonstrates how leveraging digital tools can assist in enhanced sensing, seizing, and transforming capabilities that help them integrate within the unfamiliar host environment.

2.4.1 Technology-Facilitated Resource Mobilisation

Resource mobilisation is a fundamental requirement for immigrant entrepreneurs to manage business complexities. Technology-facilitated resource mobilisation helps them overcome market embeddedness constraints through enhanced dynamic capabilities. As discussed, they face disadvantages in accessing customer, market, and supplier information necessary for business. However, digital platforms enhance the sensing opportunities by providing real-time market intelligence and seizing capabilities by building resource mobilisation capabilities.

Customer acquisition is challenging for immigrant entrepreneurs when entering a new market. However, DI helps them transcend geographical and cultural constraints. DI makes data analysis easier by using digital tools to identify market trends. Mobile applications, travel blogs, and influencer vlogs are easier tools to understand diverse customer needs, reducing the market knowledge gaps for entrepreneurs. Social media channels and e-commerce platforms provide marketing channels and reduce what literature calls ‘liability of foreignness’ (Ray 2024). For instance, engaging in cross-border e-commerce platforms may scale the market beyond the home country and can provide essential market infrastructure to

transition to a new country (Duan et al. 2021). Digital presence also helps build credibility, which they lack because of social constraints. Social media channels help brands become more visible and credible. Visibility also indicates efficient business performance, improved customer relationships, and higher satisfaction levels, which boosts credibility (Emmanuel et al. 2022). Thus, DI helps them become more credible by being more visible on digital platforms (Emmanuel et al. 2022). Mendoza et al. (2025) add another dimension to this discussion, demonstrating how immigrant entrepreneurs in El Hierro, Spain's tourism sector, introduce innovations through digital tools and social capital networks, effectively transforming local tourism offerings while preserving cultural authenticity.

Access to information has been a significant constraint for immigrant entrepreneurs. DI has enabled regulatory agencies and government websites to provide timely and updated information regarding policies and compliance requirements (Srinivasan and Venkatraman 2018). Procedures for business registrations, multilingual tax filing, and automated permit applications have transformed previously opaque bureaucratic processes into accessible and self-service digital experiences. Thus, digitalisation reduces institutional penalty, which is observed as a constraint to their success (Abd Hamid 2020). Moreover, DI initiatives such as digital payment systems, online booking platforms, and virtual tours have yielded positive results for tourism entrepreneurs in developing adaptive market capabilities to understand evolving customer preferences and regulatory requirements. Thus, DI-led technology-facilitated resource mobilisation transforms structural embeddedness from a constraint into a strategic advantage. It allows access to global markets, builds digital legitimacy, and develops sustainable business models that leverage both technological capabilities and cultural authenticity.

2.4.2 Digital Financial Inclusion and Structural Barriers

DI also empowers immigrant entrepreneurs to overcome structural barriers due to institutional embeddedness. Financial exclusion is a core strategic barrier that they face while raising startup and growth capital due to their lack of strong credit history, insufficient collateral, and discriminatory lending practices within formal financial systems (Belrhazi and Azougagh 2024). Digital financial inclusion allows them to bypass traditional banking barriers through technology-mediated funding channels. Fintech applications have democratized access to finance and reduced reliance on traditional financial channels (Butticè and Useche 2022). The ability to borrow or crowd-fund from host countries due to DI has empowered them to use their liability of foreignness as a competitive advantage. Crowdfunding benefits extend beyond capital acquisition as it signals customer validation, stakeholder legitimacy, and a market validation mechanism (Chandra 2022). Thus, the use of DI forms a dynamic

capability through which they can overcome structural embeddedness in the unfamiliar environment. Through digital financing channels, they also have a strategic advantage to leverage their transactional social networks to alternative financial mechanisms. Online peer-to-peer lending communities and diaspora investment networks provide flexible credit based on trust, shared identity, and cultural understanding rather than traditional creditworthiness metrics. DI, such as mobile microloan applications and blockchain financing, has further aggravated the importance of these alternative financing sources for them. The relationship between financial access and enterprise development emerges clearly in Ashourizadeh et al.'s (2022) findings, which reveal that formal financing stimulates innovation within immigrant ventures. Therefore, DI acts as a mediator between financial access and immigrant entrepreneurship, thereby contributing to success.

2.4.3 Digital Social Network Integration

DI, through social network integration opportunities, helps immigrant entrepreneurs overcome social embeddedness. As discussed in the previous section and evidenced in the prior literature, they face social exclusion from established local business networks, limiting access to mentorship, partnerships, and tacit knowledge (Hermann and Priem 2011). Digital learning platforms combine professional business communities and the host country's business ecosystem, allowing them to reduce their networking gap (Cenamor et al. 2019). Virtual business incubators enable rapid identification of partnership opportunities, mentorship relationships, and collaborative networks (Berger and Kuckertz 2016). Immigrant entrepreneurs, too, can leverage their cultural knowledge of their home country to build transactional relations on digital platforms. Digitalisation also assists in reducing the social challenges they face. With enhanced access to information and translation services available, entrepreneurs are better able to understand their target market and compete with stronger positioning (Yang et al. 2025). Digital communities serve as a peer review and provide feedback, which is important for product improvements. Immigrant business owners increasingly turn to online forums, social media groups, and diaspora networks to share experiences and advice on local regulations. This knowledge exchange helps entrepreneurs learn from others who have already overcome similar hurdles (Elia et al. 2020).

2.5 Sustainable Tourism Entrepreneurship and Digital Innovation Convergence

Tourism entrepreneurship has been a preferred domain for immigrant entrepreneurs to economically integrate into the unfamiliar environment. It provides opportunities to leverage cultural experiences while addressing market gaps in destination building and management (Dheer 2018). As the tourism industry increasingly adopts sustainability, it increases institutional and market embeddedness (Guo and Wang 2022). The convergence of sustainable tourism entrepreneurship and digital innovation highlights a shift in entrepreneurial ecosystems that entrepreneurs have to go through continuously. This intersection emerges as digital technologies increasingly mediate entrepreneurial processes while sustainability imperatives reshape industry expectations and market dynamics (Buhalis and Sinarta 2019). Immigrant entrepreneurs must now comply with sustainability norms while competing in dynamic digital marketplaces. The convergence of digital innovation (DI) and sustainable tourism entrepreneurship (STE), therefore, represents both an adaptation mechanism and a competitive opportunity. Digitalisation transforms how immigrant entrepreneurs acquire resources, design experiences, and interact with the ecosystem. It helps them address environmental, socio-cultural, and economic dimensions of sustainability simultaneously (Glyptou 2025). Thus, DI becomes a functional bridge that converts sustainability constraints into business opportunities. It transforms resource scarcity into efficiency, cultural knowledge into differentiation, and institutional pressure into legitimacy.

2.5.1 Dimensions of Sustainable Tourism Entrepreneurship

Sustainable Tourism Entrepreneurship (STE) is a multidimensional concept that integrates three interlinked concepts of sustainability (Shepherd and Patzelt 2011):

- Environmental sustainability: It means to optimize resource usage, reduce waste generation, and have a low-carbon footprint.
- Socio-cultural value creation: It involves focusing on heritage preservation, ensuring local participation, and equitable value sharing.
- Economic feasibility: It means that businesses eye on long-term income generation and distribution and building community resilience.

It extends beyond traditional profit maximisation objectives in tourism to providing socio-economic benefits through entrepreneurship. With inputs from Stakeholder Theory (Freeman and McVea 2005) and Resource-based View (Barney 1991), sustainable tourism entrepreneurship highlights how sustainability can act as a

revenue driver by being a competitive advantage, rather than just being compliance-driven. For immigrant entrepreneurs in tourism, STE is relevant as they have to constantly deal with resource constraints while establishing credibility in the unfamiliar environment. Embedding sustainability into their digitalised business models provides both legitimacy and differentiation in competitive markets (Kibler et al. 2015).

2.5.2 Digital Tools for Sustainable Tourism Practices

Digital technologies are enablers for sustainable tourism initiatives. They could offer immigrant entrepreneurs opportunities to implement sustainability without substantial capital investment (Buhalis and Sinarta 2019). Digital platforms enable real-time resource monitoring and efficiency analytics. For instance, a mobile-energy tracker app and IoT sensors provide insights into resource optimisation (Gutierriz et al. 2025). Cloud-based platforms facilitate environmental sustainability through carbon footprint tracking, resource consumption monitoring, waste reduction analytics, and compliance reporting.

Mobile applications enable real-time communication with local communities, supporting authentic cultural exchanges (Gretzel et al. 2015). Immigrant entrepreneurs use digital storytelling and community-based booking platforms to showcase cultural authenticity. Digital documentation of indigenous practices and traditions helps preserve them while generating income through heritage-based tourism (Yeasmin 2016). For immigrant entrepreneurs, the use of applications serves a twin purpose. They not only provide operational efficiency but also serve as legitimacy-building tools by demonstrating commitment to sustainability. For instance, the use of blockchain technology makes the tourism supply chain transparent, enabling entrepreneurs to communicate the origin of products and remove counterfeits before they reach customers.

Moreover, digital innovation reduces transaction and entry costs through e-marketplaces, fintech applications, and AI-based pricing systems. These tools help immigrant entrepreneurs secure loans and bypass traditional finance channels. Digitalised supply chains in tourism increase resilience, shorten transaction cycles, and create circular micro-economies within destinations (Luu et al. 2025). Overall, DI in tourism helps in creating a smart, sustainable tourism ecosystem.

2.5.3 Cultural Authenticity and Sustainability Integration

Cultural authenticity allows integration of sustainability through heritage preservation, local knowledge systems, and community-based tourism models (Richards 2018). Immigrant entrepreneurs possess knowledge of traditional indigenous

practices, serving as a strong competitive advantage that assists in environmental stewardship while maintaining cultural integrity. Digital platforms help them to document, preserve, and share cultural narratives to educate visitors about sustainable practices embedded within their heritage traditions. Blockchain technology can help in preserving documents for longer durations. Prior studies suggest that cultural authenticity is both a sustainability strategy and a differentiating mechanism (Uslu et al. 2023). Prior studies highlight that cultural authenticity and sustainability practices generate greater visitor satisfaction, community support, and long-term business viability (Cohen 2002). Sustainable tourism through cultural heritage or eco-tourism presents unique opportunities. It allows visitors to engage with fragile heritage sites without physical strain, aligning environmental and sociocultural sustainability goals (Poort et al. 2021). DI acts as a mediator between establishing sustainability principles and achieving cultural authenticity. Immersive experiences through virtual and augmented reality applications allow them to provide authentic experiences with minimal harm to the environment and create no impact on heritage. Additionally, IoT sensors and smart monitoring systems enable real-time tracking of environmental parameters during cultural activities. Storytelling platforms allow to narrate their cultural experiences with broader sustainability narratives. Past studies describe how immigrant enclaves maintain a strong identity and mutual support through dense social embeddedness (Yasin et al. 2025a, 2025b). This study extends that idea and proposes that digital networks may replicate or augment that identity maintenance while enabling culturally informed innovation in host markets.

2.6 Integrated Conceptual Framework: Digital Mixed Embeddedness in Sustainable Tourism

This study aims to explore how DI can effectively reduce structural barriers faced by immigrant entrepreneurs during sustainable tourism development. The theoretical underpinnings of the concepts lay the foundation for how DI helps empower them and fosters the sustainable tourism ecosystem (Figure 1). Within this framework, DI mediates the relationship between structural barriers and sustainable entrepreneurial outcomes. From the perspective of MET and Dynamic Capabilities, DI enhances three critical processes:

– Sensing: It can assist in the identification of sustainability-related opportunities through digital intelligence, such as real-time monitoring of cultural trends and their analysis.

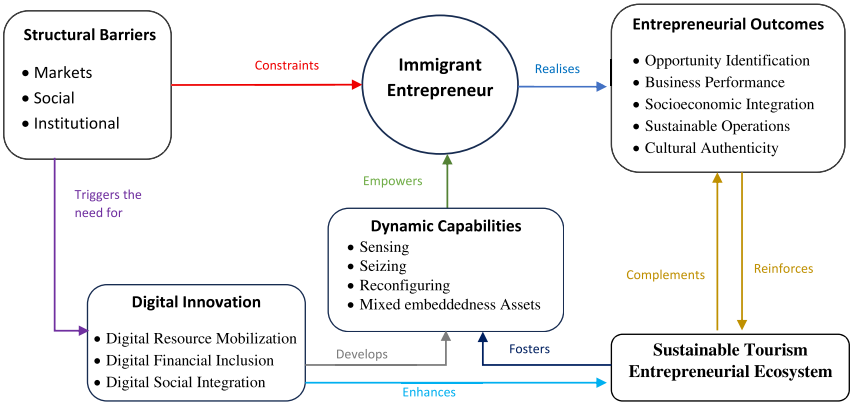

Figure 1: Integrated conceptual map of structural barriers faced by IE, digital innovation, and the sustainable tourism ecosystem.

- Seizing: It can assist in mobilising financial and social resources using fintech, mobile, and other online communities. They may be used for cross-border payments and as a source of alternative lending.
- Transforming: It can assist in reconfiguring business operations to align with environmental, cultural, and market sustainability standards. It can make the supply chain transparent and provide real-time data for decision-making.

The above discussion signifies the importance of DI in overcoming structural barriers for sustainable tourism. However, there are noticeable gaps in the existing literature that demand further exploration into the relatedness of the concepts. While the interconnection is still underdeveloped, it could benefit from exploring how individual factors, such as prior digital experience, digital knowledge, and skill level of immigrant entrepreneurs, and education, may impact their decision to digitalise in a new environment. Moreover, the importance of mentorship, incubators, business accelerators, and associations has not been evidenced in the tourism context. Other significant factors, such as cultural attitude towards digitalisation and entrepreneurship, competition, and industry-specific factors, are also not well-studied in the context of DI, sustainable tourism, and immigrant entrepreneurship. Moving beyond the factors, past literature also remains ambiguous on how structural barriers impact the dynamic capabilities, and whether DI helps in overcoming them. The present study, therefore, aims to fill in the above-mentioned gaps to improve the sustainable tourism ecosystem through immigrant entrepreneurship.

3 Methodology

3.1 Total Interpretive Structural Modelling-Polarity (TISM-P)

The present study aims to gain an understanding of how digital strategies, sustainability practices, and innovation processes interact to help immigrant tourism entrepreneurs overcome structural barriers. Seeking answers to this question requires mapping causal relationships while revealing hierarchical influences among diverse factors. Therefore, this study adopts Total Interpretive Structural Modelling-Polarity (TISM-P) as a suitable methodology to identify relationships and determine hierarchies (Shekhar and Das 2023).

The selection of TISM-P is based on several advantages it offers over other interpretive methodologies and its alignment with the research question. First, while ISM establishes hierarchical relationships effectively, it fails to answer why such relationships exist, creating potential for subjective interpretation bias. This limitation is well addressed in the TISM methodology, which explicitly documents the reasoning behind the relationships. However, TISM also suffers from a critical limitation of ignoring the existence of contradictions within the system. These contradictions occur due to trade-offs between different components in the system. TISM-P resolves it by incorporating the polarity (positive or negative) nature of the factor (Sushil 2018). The polarity helps in exploring whether the relationships have synergy (positive) or are contradictory (negative). Lastly, while quantitative methodologies like SEM establish causal linkages effectively, the use of interpretive methodologies like TISM is preferred in the exploratory stage of research, when there is a need to understand strategic tensions rather than hypothesis testing. Given that this study wanted to explore the mechanisms through which immigrant entrepreneurs adopt digital innovation, there was a need to seek answers to 'what', 'why', and' how' to completely answer the question. Moreover, in the study contexts, they may face strategic trade-offs between these mechanisms. For instance, the need for digital standardisation will always be balanced with localisation needs. Similarly, theoretically, economic sustainability may at times conflict with environmental sustainability needs. Therefore, the nature of the research question and the advantages of TISM-P in revealing both the hierarchical structure and inherent tensions simultaneously made it the preferred methodology. The detailed process of the TISM-P methodology (Figure 2) is based on the past studies (Singh et al. 2023).

Step 1. The factors are identified and arranged linearly. Then, a pairwise comparison is carried out, and transitive relationships are identified for the remaining factors.

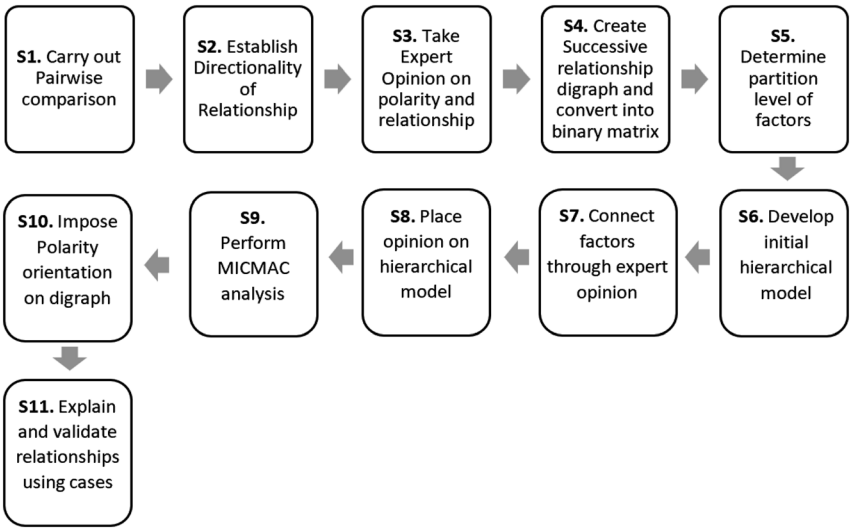

Figure 2: Steps followed in TISM-P methodology.

Step 2. The relationships are given direction and expressed as (*ij*) for forward, (*ji*) for backward, (*i* = *j*) for both ways and 0 for no relationships. Transitive relations and direct relationships are assigned +ve (positive) or −ve (negative) polarity.

Step 3. Experts confirm the identified relationship, direction, and polarity.

Step 4. A successive digraph is created by converting relationships into binary format without polarity using the following method.

If the relationship is

(ij) with +ve, then +1 in the ij cell and 0 in the ji cell;
(ij) with –ve, then –1 in the ij cell and 0 in the ji cell;
(ji) with +ve, then 0 in the ij cell and +1 in the ji cell;
(ji) with –ve, then 0 in the ij cell and –1 in the ji cell;
(i = j) with +ve, then +1 in the ij and ji cells;
(i = j) with –ve, then –1 in the ij and ji cells;
0 (no relationship), then 0 in both ij and ji cells.

In the reachability calculation, the binary conversion helps establish direct and transitive conversion. When indirect relationships are interpreted, experts evaluate whether the influence remains enabling or inhibiting based on the logical consistency of interpretive reasoning. This approach ensures that polarity retains its substantive meaning rather than being mechanically derived. However, in this process, the polarity sign itself is temporarily neutralised during the binary reachability calculation. After assigning polarity values, both +1 and −1 are converted into

1 solely for the reachability calculation. It is required to derive the structural hierarchy and establish transitivity. In this step, polarity is not discarded but preserved separately and reinstated once hierarchy levels are determined. For instance, if the relationship between any two factors is assigned as negative polarity, it is represented as −1. However, during the reachability calculation, the value is temporarily converted to binary form without a negative sign to establish hierarchy and transitive relations. Once the hierarchy levels are determined, the original polarity is reinstated in the final digraph and MICMAC interpretation at the later steps. It ensures that structural positioning is retained throughout the process, but the direction and nature of the factors are restored only in the later stages.

Step 5. Use the antecedent set, reachability set, and intersection point to determine the partition level. Once the partition level is determined, the original polarity values are reinstated on the final digraph and MICMAC outputs. It allows to differentiate between supporting and inhibiting relationships.

Step 6. A hierarchical model is developed using the identified relationships, and factors are placed based on their partition level.

Step 7. The factors are then connected through exert opinion, which determines the type of relationships between the factors, including polarity.

Step 8. The expert opinion is placed on the hierarchical model to explain the relationships and polarity in the model.

Step 9. A MICMAC analysis is performed, and factors are categorised into 4 types. The polarity nature of the factor is imposed in the analysis.

In the TISM-P model, the driving power shall be interpreted as the influence exerted by the factor in the structural model. This influence could be both inhibiting and enabling. While positive polarity denotes enabling behaviour, the negative polarity will mean inhibiting impact. This distinction is important for interpreting variables that simultaneously support certain outcomes while constraining others. In the study, a high driving power means that the factor is strategically significant and exerts a structural influence in the system. It does not directly indicate a positive strategic effect of the factor.

Step 10. The polarity orientation of the factor is imposed on the hierarchical model for better understanding and representation.

Step 11. The paths in the hierarchical model are explained using cases or expert opinion.

The research question mainly explores these key concepts: first, what factors are foundational to and what factors result from the use of digital innovations to integrate sustainability and overcome structural barriers for immigrant entrepreneurs. Second, how do these factors interact with each other? Third, whether such interaction is synergistic or contradictory. TISM-P answers these by establishing the foundational data structure through factor identification, pairwise relationships

determination with polarity, validating through experts, and converting these into a reachability matrix (steps 1–4), revealing hierarchical structure (steps 5 and 6), documenting reasons for relationships (steps 7 and 8), and determining polarity of relationships (steps 2, 9, and 10).

Ensuring replicability, the study follows a three-stage process combining literature review, expert opinion, and TISM-P. Each stage provides input for the next stage. In stage 1, factors are identified from the literature and refined through expert discussion. It results in a consolidated list of factors for analysis. In stage 2, experts provided pairwise relational judgments and polarity assessments for these factors, and these judgments produced the relationship matrix. In stage 3, experts provided an interpretation of the relationships that formed the hierarchical structuring and MICMAC analysis.

3.2 Data Sources and Sample Selection

3.2.1 Identification of Factors

The identification of factors followed a targeted scoping review of academic and practitioner literature. Based on the study objectives, it was essential to include both literature and practitioners' insights. While academic literature was intentionally kept broad to capture factors from diverse perspectives of immigrant entrepreneurship, digitalisation, sustainability, and structural barriers, practitioner literature was included only if it was published by a recognised tourism organisation, entrepreneurship support agencies, records of an immigrant entrepreneur, digital platform provider, policy institutions, or industry associations directly relevant to immigrant or tourism entrepreneurship and digitalisation. Rather than relying on a fully systematic review protocol, the content was screened purposefully targeting studies on immigrant entrepreneurship, digitalisation, sustainability, and structural barriers. Thus, the factor identification process started with literature screening, but continued with expert refinement, and concluded with expert validation. 19 factors were identified from the literature, which included research articles, industry reports, practitioner commentaries, organisational publications, and policy documents. After this, seven experts actively operating in the immigrant entrepreneurship and tourism sector were engaged in semi-structured discussions about their experiences with digital tools, sustainability practices, and structural barriers. These discussions expanded the list of factors to 32 by identifying contextual factors absent from academic literature but critical in practice (see Appendix). If a factor was recommended by an expert, it was also screened in the literature to check for some supporting conceptual or contextual evidence. Expert-given factors were

only added if they were conceptually different from the existing literature-identified factors or they had direct relevance to immigrant entrepreneurship and digital transformation processes.

Each author, individually, through independent conceptual categorisation, consolidated these factors into meaningful categories. Then, a discussion was held between the authors to arrive at common categories and labels for the identified factors (see the Appendix for the detailed process). The factors were consolidated only if they had conceptual overlap and their role in the model could not be meaningfully separated. For instance, basic digital literacy and advanced digital skills were both identified as factors. However, they were consolidated into knowledge and skills in digital tools because it would have been challenging to determine their effects separately in the model. Similarly, adoption of digital payment systems and use of financial software for management were clubbed into Digital Strategies for Financial Management. Factors that had a distinct impact on the embeddedness or might have different outcomes were retained as separate factors. This collaborative process eliminated redundancies and reduced potential biases while preserving conceptual distinctiveness. It was followed by a validation cycle in which seven subject-matter experts from entrepreneurship, tourism management, and digital innovation were interviewed first to ensure that distinct constructs had not been collapsed inappropriately, and then to assess the factors' relevance, distinctiveness, and completeness. Minor adjustments and refinements were made based on expert advice, and a list of 17 factors was compiled (Table 1). The list was accompanied by clear operational definitions and explicit connections to the study's research framework (Appendix A). This rigorous identification process ensured both theoretical grounding and practical relevance.

The finalised factors in the study perform different roles in the digital transformation mechanism for an immigrant entrepreneur to address embeddedness. Thus, they may not operate at a similar analytical level within the hierarchical model. A few factors are enabling conditions, such as knowledge and skills in digital tools, adoption and use of digital tools, and digital skills training that begin the process of digital transformation. Similarly, some factors focus on capacity-building and relationships, such as collaborative innovation networks, community engagement, and cultural intelligence and adaptability. This is significant as immigrant entrepreneurs often rely on network support, informal learning, and adaptive relationships to overcome institutional and market constraints in unfamiliar environments. Therefore, these relationship-building factors may be regarded as bridging mechanisms through which foundational self-skills may be utilised in the transformation.

Additionally, factors such as integrated sustainability practices, customer engagement, and measuring the success of digital innovation may act as strategic

Table 1: List of factors identified from literature review and expert opinion.

Code	Factors	Key references
F1	Knowledge and skills in digital tools	Gurău et al. (2020)
F2	Adoption and use of digital tools	Rahman et al. (2021)
F3	Impact of digital tools on overcoming barriers	Duan et al. (2021), Erinc Oztas (2024), Belrhazi and Azougagh (2024)
F4	Integrated sustainability practices	Goriup and Ratkajec (2021), Poggesi and Mari (2025)
F5	Customer engagement and digital personalisation	Duan et al. (2021)
F6	Community engagement and local networking	Belrhazi and Azougagh (2024)/Elia et al. (2020)
F7	Digital strategies for financial management	Duan et al. (2021)
F8	Regulatory and legal digital adaptation	Belrhazi and Azougagh (2024)
F9	Measuring the success of digital innovation	Belrhazi and Azougagh (2024), Ostrovsky and Picot (2021), Brown and Brown (2019)
F10	Challenges in adopting digital tools	Drydakis (2024), Neumeyer et al. (2020)
F11	Digital skills training and continuous learning	Drydakis (2024), Li et al. (2018)
F12	Future plans for digital innovation	Duan et al. (2021), Nambisan et al. (2019)
F13	Cultural intelligence and adaptability	Yang et al. (2025); Chen (2024)
F14	Collaborative innovation networks	Gomez et al. (2020), Elo and Minto-Coy (2018), Smith et al. (2017)
F15	Resilience and crisis management	Vershinina and Rodgers (2023), Rahman et al. (2021), Andrejuk (2022)
F16	Sustainability-driven value proposition	Gurău et al. (2020), Poggesi and Mari (2025)
F17	Digital transformation for sustainovation	Lee et al. (2026); Belrhazi and Azougagh (2024)

conditions that may assist immigrant entrepreneurs to translate digital capabilities into improved market positioning, stakeholder legitimacy, and sustainability-oriented adaptation. Lastly, resilience and crisis management, sustainability-driven value proposition, and digital transformation for sustainovation can be regarded as outcomes of the digital transformation process. Since the factors have different conceptual meanings and they also operate at multiple analytical levels, all the factors were retained in the analysis. This categorisation also provides a foundation for the TISM-P analysis by clarifying which factors may primarily initiate transformation, which might support capability development and embeddedness reconfiguration, and which might emerge as higher-order strategic outcomes. This is

useful as hierarchical relationships in TISM-P frameworks are established based on driving-dependence parameters.

3.2.2 Selection of Expert Sample

The initial expert sample consisted of the same seven experts used in the factor identification stage, ensuring continuity and contextual familiarity with the study's objectives. These experts included immigrant entrepreneurs in tourism (n = 2), tourism industry professionals (n = 2), sustainability specialists (n = 1), and digital innovation consultants (n = 2). All the selected experts met three set conditions: (1) minimum five years of professional or academic experience, (2) have expertise in at least two of the core dimensions of the study, and (3) have no direct or indirect commercial relationship with each other. The expert panel had diverse functional and professional roles across tourism, digital innovation, sustainability, and immigrant entrepreneurship. The study did not focus on geographic attributes such as country of operation or urban-rural setting. This was pre-decided as the focus was more on experiential input rather than studying spatial variation. This is regarded as a study design limitation, and future studies may incorporate spatial variation to study cross-context variation in expert recommendations.

The expert panel was subsequently expanded during the model development and validation stages to ensure judgment stability and consensus building. The final sample of experts consisted of 14 experts, selected through purposive sampling, to ensure diverse perspectives while maintaining methodological rigour. The panel included immigrant entrepreneurs (n = 4), tourism industry professionals (n = 3), sustainability specialists (n = 2), and digital innovation consultants (n = 5). The final hierarchical model, relationships, and polarity determination are therefore based on the collective assessment of the final fourteen experts rather than the initial seven experts.

3.2.3 Expert Validation and Consensus Building

The expert-based relationship validation followed a structured multi-round consensus procedure with the initial seven experts, conducted in 2024. In Round 1, a pairwise relationship was established with the factors, and initial polarity was identified based on expert recommendations. Round 2 focused on clarification of relationships where initial agreement fell below 60 %. In Round 3, the discussion was related to building agreement, as relationships were to be retained only after consensus exceeded 75 % for both direction and polarity. Disagreements were resolved through explanation exchange and discussion. Equal weightage was given to all the experts, and sequential inputs were collected to avoid group bias. The lead

author moderated this exercise but did not exercise any pressure to override the expert decision. Lastly, no single expert opinion-based relationship was adopted.

Even after three consensus-building rounds, several relationships remained below the determined consensus level of 75 %. Subsequently, the expert panel was expanded, and seven additional experts were sequentially invited to assess the relationships between the factors. This was done to ensure there is stability in judgment rather than enforcing the consensus. It was not a pre-decided approach; however, since the initial experts failed to reach a desired consensus, this approach was followed. After including each additional expert, the matrix was recalculated, and telephonic discussions were held to reach an agreement. This process resulted in reaching the desired consensus threshold at the 13th expert. An additional expert was then invited to check for relationship stability. Since no substantial agreements in consensus were observed after the final expert inclusion, the process was concluded.

The sample size is sufficient for studies adopting the interpretive structural methodology. Past studies have an average of five to seven experts in their sample size for relationship identification and validation (Dhir and Dhir 2020; Menon and Suresh 2021; Zhao et al. 2020).

To mitigate any selection bias, it was ensured that respondents had no direct commercial contact with each other or with any of the lead authors. To establish the reliability, a multi-stage process was followed. First, factors were identified independently by the experts, but their relationships were established and validated by combining inputs from all the experts. Second, a document trail of all experts, all expert inputs, interpretive statements, and the rationale for each relationship was maintained to increase transparency. Lastly, disagreements in viewpoints occurred at multiple stages of the process and contributed meaningfully to shaping the final structure, particularly in establishing the relationships and while finalising the model. Initially, there were differences in views on whether a sustainability-driven value proposition should be understood as a constraint that limited entrepreneurial choices or as an enabling condition that expanded them. It led to discussions with the experts for clarification of contextual meanings. During the discussions, experts clarified the contextual meaning of each relationship. For instance, one expert suggested that ‘sustainability-driven value proposition sometimes restricts immediate entrepreneurial options for immigrant entrepreneurs’, noting it as a driver constraining strategic choices. Whereas another expert considered it to be an outcome and noted that ‘such propositions create long-term trust and legitimacy in the host community’. This created a dual interpretation of the factor’s role in the model, which was resolved through a clarification round. Both experts were presented with the situations, and a discussion was held. After that, it was concluded that although sustainability-driven value propositions may influence certain

decisions, they primarily manifest as an outcome shaped by deeper digital and sustainability mechanisms. A similar divergence in interpretation was observed for Collaborative Innovation Networks. Some experts viewed it as a foundational driver, explaining that 'collaboration is the starting point that gives immigrant entrepreneurs access to digital knowledge, market exposure, and problem-solving resources.' Others noted it as an outcome that strengthens 'only after entrepreneurs have achieved a certain level of digital maturity.' We reached out to the disagreeing experts and showed them both plausible explanations. Then, after discussion, it was agreed that it is an enabling condition that unlocks access to resources and accelerates subsequent digital and sustainability outcomes.

As the process progressed, new interpretive differences arose when the experts worked on establishing the relationship and polarity. A few experts argued that knowledge and skills in digital tools are an autonomous action which should act as a linkage factor. However, the majority of experts viewed it as a deeper, foundational driver influencing all subsequent digital decisions. To address this, explanations from both agreeing and disagreeing experts were presented to each other to make them understand views. Once more than 75 % agreement was reached on both relationship direction and polarity, the decision was finalised for that factor. For instance, in the discussion surrounding Knowledge and Skills in Digital Tools, consensus was eventually reached that its dual role of prerequisite and positive driver shall be reflected in the final model structure. It added conceptual depth to the final hierarchy by distinguishing foundational skills from strategic-level innovation drivers. This process ensured that the final output is based on collective judgment rather than individual bias.

3.2.4 Primary Data Collection

Primary data were collected through a multi-phase expert interview process. First, seven experts were interviewed to identify context-specific factors beyond those found in the literature. The experts then validated the relevance and distinctiveness of the factors. In the following phase, the expanded expert panel assessed the direction, polarity, and rationale of the relationships between factors. Finally, experts rated the strength of the identified relationships and reviewed the path diagram, supporting the establishment of the hierarchical structure.

Interviews in all the phases were conducted through a combination of in-person meetings and virtual conferences based on expert availability and geographic location. Most of the interviews were conducted in English; however, on several occasions, native languages were used to ensure that respondents felt at ease in expressing their views. The interviews were then translated using professional services into English to control for any errors in data collection. Any inconsistencies

were documented and rectified through further clarifications with the respondents. While collecting the data, the lead author ensured that the respondents were aware of the ethical guidelines, such as informed consent, confidentiality assurances, right to withdraw, and data protection protocols. Interview recordings and transcripts were stored securely and anonymised to protect participant identities while maintaining data integrity throughout the analysis process.

4 Hierarchical Modelling of Factors through TISM-P

After identifying the factors, they are linearly arranged for pairwise comparison. The results reflect expert interpretation of the relationships rather than establishing any causality claims validated by empirical evidence. The lead author, with the help of experts, assessed the initial relationships between the factors. For instance, since experts noted that digital knowledge and skills are foundational to the adoption of digital tools, the relationship was termed F1, leading to F2. Experts noted this relationship to be foundational and critical, as digital literacy avoids uncertainty about capabilities. It allows immigrant entrepreneurs to select appropriate technology rather than avoiding it due to unfamiliarity. An expert noted that "this path is significant because immigrant entrepreneurs often lack access to formal digital knowledge and training. They depend on self-acquired knowledge or on peer groups to build knowledge for digital tools adoption." Similarly, experts described that the enhanced adoption of digital tools assists in navigating through structural barriers. Therefore, the relationship was marked from F2 to F3. An expert positively commented on this relationship, "digital platforms allow us to bypass institutional barriers. We use crowdfunding to bypass traditional financial channels, exclusion, and social media to overcome advertising barriers." Since F1 leads to F2 and F2 leads to F3, F1 leads to F3 through transitivity. It was interpreted by experts as reflecting a perceived cascading influence of digital knowledge that helps in mitigating

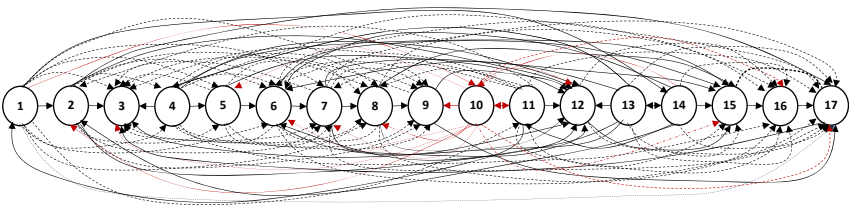

Figure 3: Initial successive digraph. Note: Direct relationships are shown as straight lines; dotted lines show transitive relationships.

structural barriers. The relationship is established for other factors similarly, and a successive relationship digraph (Figure 3) is obtained from the analysis.

The initial successive digraph is then converted into a binary matrix. All the direct positive and transitive positive relationships are transformed into +1, and all the direct and transitive negative relationships are coded as −1 in columns *ij*. The same relationship for *ji* is coded as 0. The negative orientation of relationships is then temporarily suspended. For instance, the relationship between Challenges in Adopting Digital Tools (F10) and Adoption and Use of Digital Tools (F2) was assigned a negative polarity, as an increase in adoption barriers may restrict the adoption of digital tools. During reachability calculation to determine structural positioning, the negative orientation is temporarily overlooked, and the relationship is coded as 1. Then, we calculate the total driving power of the factor and then segment it into positive driving power and negative driving power. For the factors with more positive driving power, the nature of the factor is positive. Therefore, within the structural hierarchy, F1, F2, F11, and F14 all have enabling behaviour as their positive polarity relationships outweigh the inhibiting influences.

Once the hierarchy levels were determined, the original negative polarity was reinstated in the final digraph and MICMAC interpretation. Thus, F10 retained its structural significance within the hierarchy while continuing to represent an inhibiting rather than enabling influence in the final interpretation. An expert provided more insights into it by saying, "The negative polarity of F10 has twin effects: it directly hinders digital tool use while simultaneously pushing immigrant entrepreneurs to rely more heavily on collaborative networks for support." Another expert commented that the negative polarity of F10 shows that the implementation barriers are not isolated concerns, but rather shape the strategic choices at every stage.

Similarly, the dependence level of the factors is counted and then segmented into positive dependence and negative dependence. So, in the study, we have only positive outcomes since the factors had more positive dependence than negative. This pattern suggests that when foundational capabilities and linking mechanisms work well, multiple positive outcomes emerge together rather than requiring trade-offs. Then, based on the reachability set (driving power), antecedent set (dependence level), and intersection point, the partition level of the factors was determined.

In the study, F1, F14, F02, F11, and F10 have high driving power and have low or negligible dependence levels and are therefore placed at the bottom of the hierarchical level. An expert noted that immigrant entrepreneurs must have basic digital knowledge, develop collaborative networks, engage in digital training, and plan for future innovation to integrate sustainability and overcome structural barriers. Notably, experts positioned adoption challenges as a significant driver, indicating their impact on future strategic choices. Similarly, F12, F15, F16, and F17 have

negligible or low driving power, and very high dependence levels are then placed higher in the hierarchy. These outcome factors depend upon the preceding driver factors. Within the hierarchy, Digital transformation (F17) appears at the top and shows that experts interpret that comprehensive digital transformation is not a starting point but the ultimate result of accumulated capabilities, network development, and strategic adaptations. One immigrant entrepreneur noted that for him, digital transformation is not merely implementing enterprise-level technology systems, but having sufficient digital capabilities to compete in industry ecosystems.

The hierarchical diagram is converted into a binary table asking for the relationship's nature and identifying if any transitive relationship exists (Table 2). The experts then identified the possible reasons for the hierarchy established (Figure 4). For instance, experts recommended that F1 may have a positive influence on F14 because digital skills and knowledge may increase the chances for future innovation collaboration. An expert commented that when tourism immigrant entrepreneurs understand digital technologies better, they can develop forward-looking strategies rather than just reacting to immediate problems.

Table 2: Binary matrix showing the relationship and polarity of factors.

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	–	+1	+1	+1	+1	+1	+1	+1	+1	−1	+1	+1	0	+1	+1	+1	+1
2	0	–	+1	+1	+1	+1	+1	+1	+1	0	0	+1	0	0	+1	+1	+1
3	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	+1	–	+1	+1	+1	+1	+1	0	0	+1	0	0	+1	+1	+1
5	0	0	0	0	–	+1	+1	+1	+1	0	0	+1	0	0	+1	+1	+1
6	0	0	0	0	0	–	+1	+1	+1	0	0	+1	0	0	+1	+1	+1
7	0	0	0	0	0	0	–	+1	+1	0	0	+1	0	0	+1	+1	+1
8	0	0	0	0	0	0	0	–	+1	0	0	+1	0	0	+1	+1	+1
9	0	0	0	0	0	0	0	0	–	0	0	+1	0	0	+1	+1	+1
10	0	−1	−1	−1	−1	−1	−1	−1	−1	–	+1	−1	0	0	−1	−1	−1
11	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	–	+1	0	0	+1	+1	+1
12	0	0	0	0	0	0	0	0	0	0	0	–	0	0	+1	+1	+1
13	0	0	0	+1	+1	+1	+1	+1	+1	0	0	+1	–	0	+1	+1	+1
14	0	+1	+1	+1	+1	+1	+1	+1	+1	−1	+1	+1	+1	–	+1	+1	+1
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	+1	+1
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+1	–	+1
17	0	0	+1	0	0	0	0	0	0	0	0	0	0	0	+1	0	–

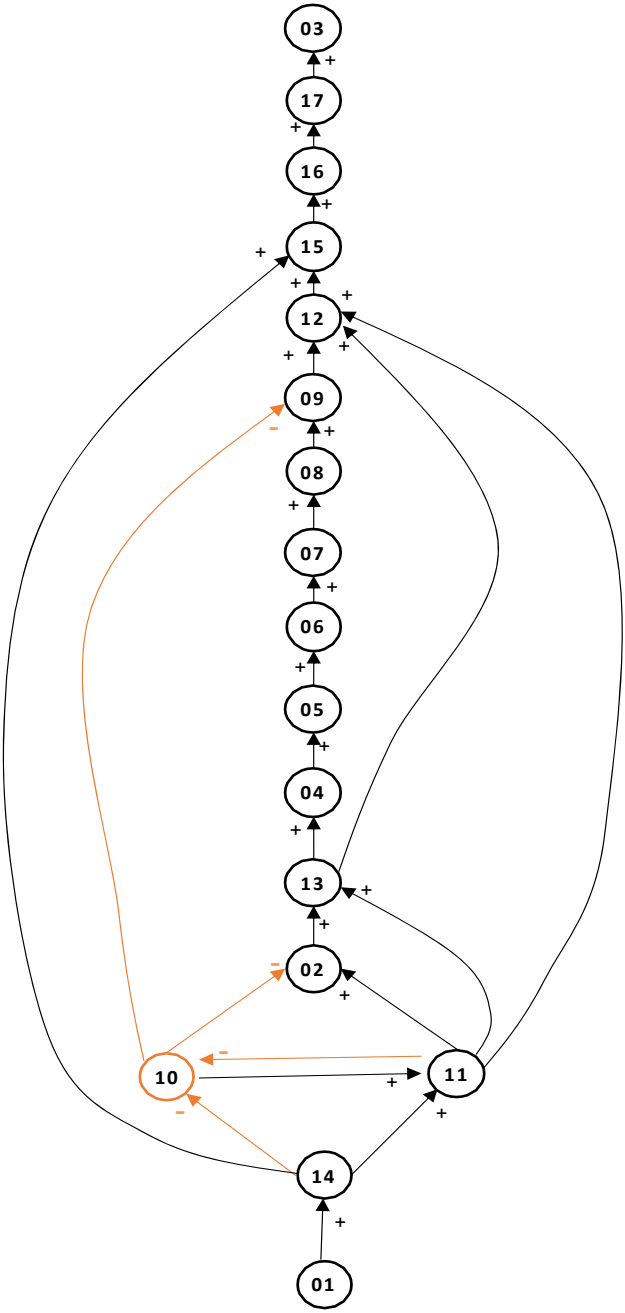

Figure 4: Initial hierarchical model showing relationship and polarity.

Similarly, the negative relationship between F10 and F2 was because increasing challenges in adoption may discourage the use of digital tools. Experts gave two sets of reasons for this: one explained that barriers increase psychological concerns, such as stress, anxiety, and fear of failure. Others commented that practical obstacles may be a reason for adoption barriers. However, a few experts commented that the presence of adoption barriers may also lead to strengthened collaborative networks as immigrant entrepreneurs seek peer support for troubleshooting and knowledge sharing. The experts were then asked about the possible explanation for other relationships, and an interpretation table was obtained in the analysis (Table 3). Two significant relationships were interpreted by the experts. Firstly, as per them, the relationship between F2 and F5 meant that networks help immigrant entrepreneurs understand host country business norms while providing platforms to showcase their origin country cultural assets. This cultural authenticity is important in tourism, where it is a strong marketable asset, noted an expert. Second, the relationship between F6 and F7, as per the experts, meant that by developing crisis resilience through digital innovation, tourism entrepreneurs view sustainability as operational risk management rather than idealistic environmentalism. The interpretations from experts are imposed to get the final TISM digraph (Figure 5). The factors are then categorised into four. As established in the methodology, high driving power reflects stronger structural significance, which may be enabling or inhibiting. Thus, a factor may possess a strong driving influence while still exerting inhibiting or constraining effects within the hierarchy.

a. Drivers with very high driving power and low dependence level. F1, F2, F4, F10, F11, F13, and F14 are drivers in the study, with F10 being a negative driver, whereas the others are positive. This suggests that enabling drivers may help offset the inhibiting influence associated with adoption barriers. It will maintain crisis resilience, integrate sustainability, and overcome barriers.
b. Outcomes with low driving power and very high dependence. In this study, F3 F8, F9, F12, F15, F16, and F17 are the outcomes. All the outcomes are positive. It indicates that once critical capability thresholds are reached, multiple strategic benefits emerge simultaneously.
c. Linkages with moderate driving power and dependence level. In this study, F5, F6, and F7 are positive linkages. These factors act as a bridging mechanism; they are influenced by the drivers and are necessary to achieve the outcomes. For

Table 3: Experts' interpretation of the determined relationship.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Makes it easier to adopt digital tools												Knowledge enables cross-cultural collaboration for innovation networks			
2	–	Digital adoption enhances barrier reduction														
3		–														Enables overcoming systemic challenges
4			–	Sustainability fosters personalized customer engagemen.												
5				–	Personalization strengthens local community connections											
6					–	Networking improves financial management strategies										

Table 3: (continued)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
7						–	Financial strategies aid regulatory adaptation.									
8							–	Compliance enhances digital innovation measurement								
9								–			Innovation success guides future digital plans					
10	Adoption challenges discourage digital tool usage							Adoption challenges hinder innovation measurement	–	Adoption challenges hinder continuous learning						
11	Continuous learning enhances digital adoption								Learning difficulties reinforce adoption barriers	–	Continuous learning fosters future digital innovation					
12											–			Future innovation plans enhance crisis resilience		

Table 3: (continued)

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
13		Cultural adaptability supports sustainable business integration								Shapes future digital strategies	–				
14								Innovation networks create complexity, increasing adoption challenges	Collaboration enhances knowledge exchange and continuous digital learning		Innovation networks improve cultural adaptability	–	Networking eases tackling operational challenges		
15													–	Resilience enhances sustainability-driven value	
16														–	Sustainability value accelerates digital transformation

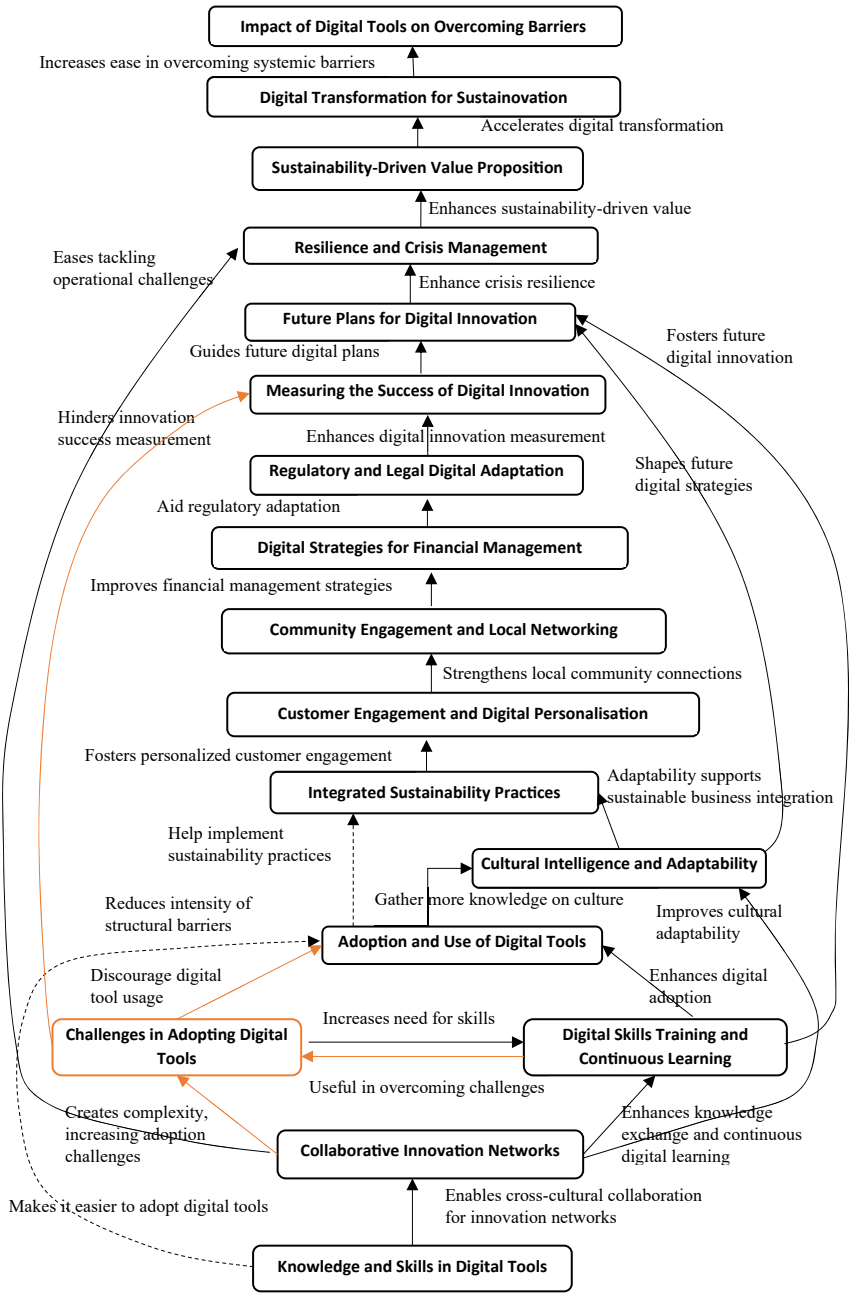

Figure 5: TISM digraph showing the detailed relationship between factors. Note: Direct relationships are shown as straight lines; dotted lines show transitive relationships.

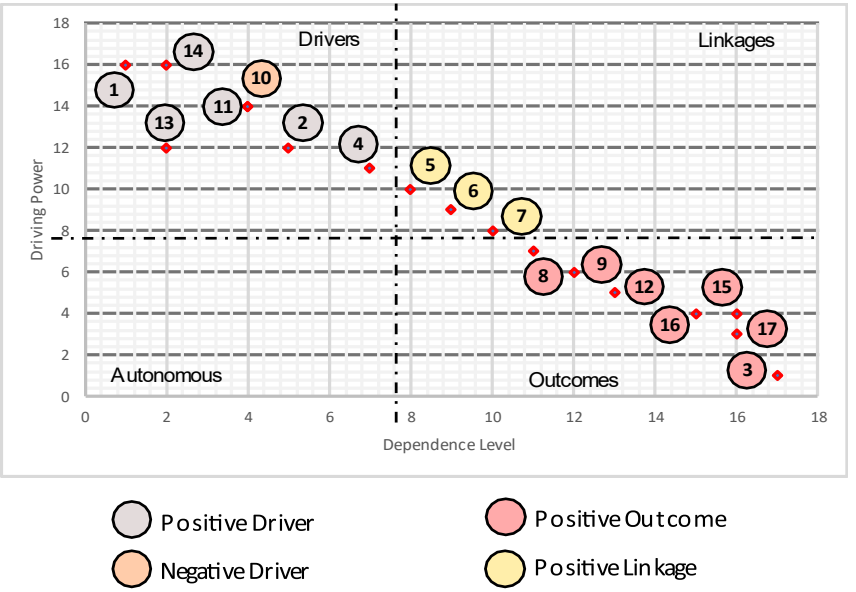

Figure 6: MICMAC analysis with factor polarity.

Table 4: Final binary matrix showing factor interrelationships.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	–	+1*	0	0	0	0	0	0	0	0	0	0	0	+1	0	0	0
2	0	–	0	+1*	0	0	0	0	0	0	0	0	+1	0	0	0	0
3	0	0	–	+1	0	0	0	0	0	0	0	0	0	0	0	0	+1
4	0	0	0	–	+1	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	–	+1	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	–	+1	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	–	+1	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	–	+1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	–	0	0	+1	0	0	0	0	0
10	0	−1	0	0	0	0	0	0	−1*	–	+1		0	0	0	0	0
11	0	+1	0	0	0	0	0	0	0	−1	–	+1	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	–	0	0	+1	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	0	0
14	0	0	0	0	0	0	0	0		−1	+1		+1	–	+1*	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	+1	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	+1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–

*Means Transitive relationships.

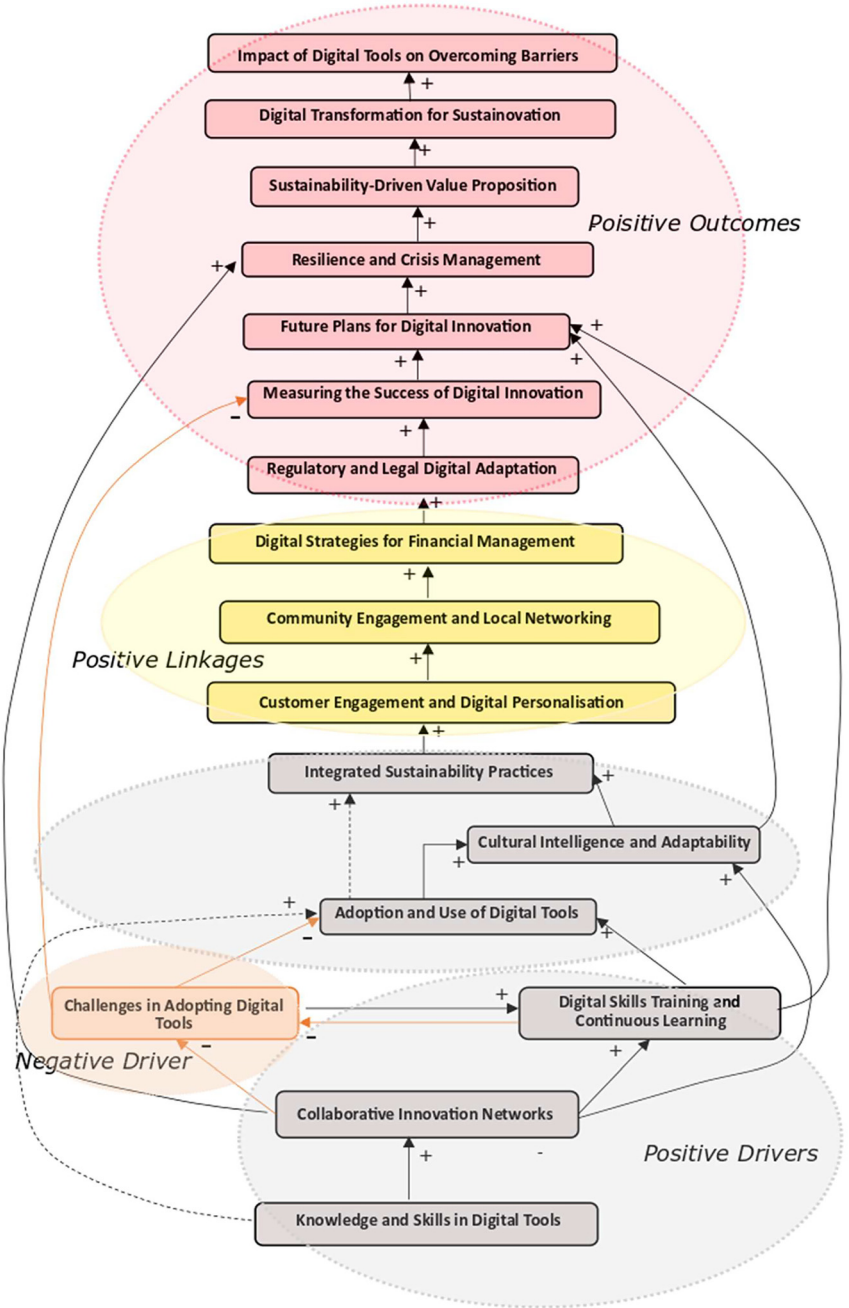

Figure 7: Final digraph with relationship and classification. Note: Direct relationships are shown as straight lines; dotted lines show transitive relationships.

instance, cultural intelligence develops through market interaction, which builds crisis resilience, emerging from digital flexibility during disruptions.

d. Autonomous with low driving power and dependence level. These are uncontrollable and unrelated factors with limited connection to the overall model. No such factor was observed in the study.

The results of the MICMAC (Figure 6) and the hierarchical model align with each other. The driving factors are placed at the bottom of the digraph. The negative driver shows negative arrows emerging from other factors, illustrating how experts perceive that adoption challenges spread detrimental effects across multiple capabilities. The linkages are placed in the middle of the digraph, demonstrating their role in converting foundational capabilities into strategic outcomes. The outcomes acquire the top half of the model, representing achievements dependent on the successful navigation of all preceding stages. A final matrix indicating factor relationships and polarity is drawn (Table 4). Finally, the results are superimposed on the hierarchical digraph (Figure 7) to give readers a clear view of how these factors interrelate.

5 Discussion

The results support the idea of reconfigurable embeddedness as experts perceive that digital capabilities shape how entrepreneurs relate to markets, communities, and institutions. In the study, these pathways are not discussed as empirical evidence but as an exploratory mechanism that shows that digital capabilities allow entrepreneurs to adjust their relationships with markets, communities, and institutions. This reconfiguration is interpreted by experts as a pathway through which they overcome structural barriers and access alternative resource spaces, which in turn contribute to sustainability-oriented outcomes.

The study findings provide useful insights for immigrant entrepreneurs tackling systemic structural challenges in tourism. It offers a structured interpretive framework that may guide and answer why and how they shall undertake digital transformation as a tool to tackle challenges. Knowledge and skills in digital tools are perceived as a foundational stepping stone. This knowledge base is perceived to positively influence the formation of "Collaborative Innovation Networks," suggesting that as they develop digital literacy, they become more capable of forming valuable collaborative relationships.

These innovative networks, in turn, positively impact several critical areas:

- They provide opportunities for digital skills training and continuous learning. Experts indicated that learning opportunities and acquired skills are closely associated with progress toward digital transformation (Autio et al. 2018).
- They are a source of cultural intelligence and adaptability. These innovative networks help facilitate easy assimilation into the new culture (Ang et al. 2007). The acquired knowledge helps increase adaptability and helps induct into the new environment and overcome the structural barriers.
- The innovative networks are a source of digital tools. By engaging with these networks, immigrants may be persuaded to adopt and use digital tools in business more frequently.

The hierarchical model further highlights how experts interpret and perceive that the foundational digital knowledge and skills create an initial learning ecosystem for immigrant entrepreneurs to overcome structural barriers (Kraus et al. 2019; Vial 2021). Additionally, it then highlights the impact of the sole negative driver, "Challenges in Adopting Digital Tools", which experts perceive to create inhibiting relationships.

- By making it difficult for entrepreneurs to adopt and use digital tools by posing difficulties such as the cost of acquiring resources, competition from others in resource usage, and limited technical expertise among small businesses in digital tool usage (Maroufkhani et al. 2020).
- By increasing the need for new digital skills training, it makes the existing training redundant as new challenges emerge, and they have to put in more effort to strengthen their digital presence (Bican and Alexander 2020).
- Inconsistent implementation, fragmented data usage, and skewed baselines that distort performance indicators such as ROI calculations make it difficult to measure the success of digital innovation.

While these challenges consist mainly of internal barriers, the model suggests that addressing these may expose immigrant entrepreneurs to external constraints, revealing a broader paradox in the digitalisation process. As the investment in digital tools to address these increases, it also enhances exposure to external threats beyond control. For example, increasing dependence on global digital platforms can make entrepreneurs more vulnerable to fluctuating market demand, changes in platform algorithms, and intensified international competition. This interpretation suggests that while local constraints may get addressed, it simultaneously increases sensitivity to global market volatility. For instance, several immigrant entrepreneurs run homestays and tour services and increasingly depend on global booking platforms such as Airbnb, Agoda, and Booking.com to bypass local visibility constraints. Although it works well to overcome local and market embeddedness, it exposes them

to global volatility and digital risks. Any change in pricing or visibility algorithms can reduce their visibility overnight. Moreover, any change in global conditions can directly affect revenues, regardless of stable local conditions. This discussion provides a more balanced understanding of how digitalisation eases certain structural constraints while amplifying exposure to global market risks. Therefore, the counterforce created by the negative driver needs to be addressed through targeted interventions with twin objectives. First, overcoming structural barriers, and second, building adaptive capacities while managing digital risks. The hierarchical model suggests that collaborative networks and more training to improve digital skills can significantly aid in overcoming these barriers (Urban et al. 2024).

The middle section of the hierarchical model is interpreted as showing how experts view the effect of positive linkages, highlighting the role of digital transformation in building community and customer relationships. The linkages identified in the findings reveal how integrated sustainability practices positively influence both customer engagement and digital personalisation, community engagement, and local networking (Baumgartner 2014). This suggests that immigrant entrepreneurs who incorporate sustainability into their business models can more effectively engage with customers and communities. The impact of the linkage factors is transmitted to improved financial management through digital strategies. It confirms that effective customer and stakeholder engagement strategies translate into improved financial outcomes, which holds significant importance for immigrant entrepreneurs who often face financial barriers in the new environment.

The top part of the hierarchical model explains what experts perceive to be the positive strategic outcomes of digitalisation. Monitoring success measurement parameters and ensuring that they are achieved lays the foundation for future digitalisation planning, a better crisis management model, and value proposition development. Finally, these factors lead to digital transformation for sustainability, suggesting an integral interaction between sustainability and innovation through digital means. Thus, the hierarchical model clearly illustrates how immigrant entrepreneurs can evolve from basic digital adoption to strategic transformation of their businesses through sustainable innovation.

Although the linkages identified in the analysis may be co-evolutionary, the adopted methodology TISM-P, models them as hierarchical based on expert interpretation. The model, therefore, does not claim to capture full bidirectionality or temporal feedback. Three most critical linkages define the model that shapes the systemic logic of digital transformation for immigrant entrepreneurs. First, the relationship between positive drivers and the negative driver, challenges in adopting digital tools, which affect the pace of adoption, intensity of training needs, and the stability of the learning process. Second, once these hindrances are addressed, Integrated Sustainability Practices emerge as the central linkage mechanism that

connects digital adoption with personalisation, customer needs, and improved financial management. Thus, sustainability acts more as a strategic linkage rather than an outcome for immigrant entrepreneur in their digital adoption. Third, managerial capabilities impact final outcomes like regulatory and legal digital adaptation, improved success measurement, future digital planning, resilience building, which are required for digital transformation for sustainovation. These three linkages explain how digital innovation becomes a tool for overcoming structural barriers.

5.1 Critical Path Analysis

The hierarchical model generated through TISM-P shows several paths connecting foundational drivers, linkage mechanisms, and sustainability-oriented outcomes. For immigrant entrepreneurs, these are pathways through which they can attain digital transformation to overcome systemic structural barriers while borrowing insights from Mixed Embeddedness theory and Dynamic Capabilities theory. In the study, of the several paths, only four key pathways covering most of the identified factors are discussed. These paths are selected for three key reasons. First, they represent the most dominant relationship sequences identified in the hierarchical model. Second, they capture most of the polarity relationships in the model. And third, collectively, these four paths explain how experts understand digital innovation to reshape the way immigrant entrepreneurs work within different embeddedness domains, turning perceived constraints into potential capability-building opportunities. Thus, findings do not claim that embeddedness is transformed causally, but rather show how experts understand and perceive it to shift from static constraint to dynamic opportunities through digitalisation. Table 5 provides a summary of these critical paths, their dominant polarity patterns, and the reasons they are treated as strategically important within the model. The criticality or significance of these paths is defined by their structural influence in the hierarchical model, reflected in two parameters. First, they should represent major driver-linkage-outcome relationships, and second, they should cover maximum enabling and inhibiting polarity relationships. These paths are prioritised based on expert interpretation regarding their criticality and strategic importance in explaining how digital adoption assists immigrant entrepreneurs in overcoming structural barriers and pursuing sustainability-oriented transformation. These paths have overlapping context for two key reasons. First, they share some foundational factors, and second, they all have a final objective of digital transformation. However, since their origin,

Table 5: Summary of key pathways and polarity patterns.

Path no.	Pathways of different factors	Dominant polarity pattern	Expert interpretation for significance
Path 1	Knowledge building → collaborative networks → crisis and resilience → sustainability-driven value proposition → digital transformation	Primarily positive polarity	It captures how collaborative embeddedness and resilience mechanisms support sustainability-oriented transformation
Path 2	Knowledge building → collaborative networks → cultural intelligence and adaptability → future plans for digital innovation	Primarily positive polarity	It explains how social and market embeddedness interact to strengthen adaptive and forward-looking digital capabilities
Path 3	Knowledge building → collaborative networks → challenges in adopting digital tools → measuring success of digital innovation	Mixed polarity with inhibiting influences	It highlights how structural constraints and negative polarity relationships trigger adaptive learning and necessity-driven innovation
Path 4	Knowledge building → collaborative networks → digital skills training and continuous learning → future plans for digital innovation	Primarily positive polarity	It demonstrates how continuous capability renewal supports long-term digital adaptability and strategic transformation

structural progression, and combination of intermediary factors differ, these are taken as distinct pathways in the study. Therefore, path 1 is more concerned with building resilience for sustainability transformation, whereas path 4 focuses more on capacity building and continuous learning for sustainable digital transformation.

5.1.1 Path 1. Knowledge Building → Collaborative Networks → Crisis and Resilience → Sustainability Driven Value Proposition → Digital Transformation

This path highlights how experts interpret that digital literacy may transform social embeddedness, as existing digital knowledge and skill-building lead to collaborative networks. Unlike traditional immigrant networks bounded by geographic proximity and ethnic ties, digitalisation helps in creating geographically dispersed, purpose-driven collaborative networks. These are critical in enhancing resilience and developing crisis management, which leads to sustainable value creation (Purnomo et al. 2021). For instance, tourism refugee entrepreneurs often create online communities to help each other in economic downturns. This digital transformation of

network structure represents a shift from bonding social capital to bridging social capital.

This path also highlights how businesses can sense sustainability opportunities, drawing insights from dynamic capabilities theory. Experts interpreted that digital ties allow them to detect market shifts towards responsible operations. It allows them to seize the opportunity as the collaborative networks help in resource mobilisation and distribution during crises. For instance, sustainability-focused business models to create crisis resilience were widespread among entrepreneurs during the COVID-19 pandemic (Santos et al. 2023; Toanoglou et al. 2022). This helps businesses in transforming by reconfiguring their business models to embed sustainability in core operations rather than treating it as a reactive adaptation (Dabić et al. 2020).

5.1.2 Path 2. Knowledge Building → Collaborative Networks → Cultural Intelligence and Adaptability → Future Plans for Digital Innovation

This path reveals the interdependence between social embeddedness and market embeddedness. While collaborative networks provide knowledge to overcome the institutional embeddedness, the digital expertise helps immigrant entrepreneurs decode the market signals to network intelligence. Past literature confirms that in the tourism sector, immigrant entrepreneurs utilize digital literacy programs to build cross-cultural business networks that enhance their adaptive capabilities (Kloosterman and Rath 2001).

These cross-cultural networks provide them with enhanced cultural intelligence to perform continuous market sensing. Furthermore, cultural adaptability allows one to seize the opportunity by tailoring offerings to host market contexts without abandoning distinctive ethnic value propositions. Additionally, experts noted that they transform their business by utilizing their network-enhanced cultural intelligence to develop forward-looking digital strategies integrating host countries' values within their business and personal value system (Ang et al. 2007). The progression from existing knowledge to plans for digital innovation through collaborative networks is often observed in the literature, where those who combine technical knowledge with cultural insights through collaborative learning develop more innovative long-term digital strategies than their non-immigrant counterparts.

5.1.3 Path 3. Knowledge Building → Collaborative Networks → Challenges in Adopting Digital Tools → Measuring Success of Digital Innovation

Challenges in adopting digital tools originate from distinct embeddedness dimensions with different manifestation patterns. Institutional embeddedness

challenges include limited access to government digital support programs due to language barriers, regulatory uncertainty for cross-border operations, and a lack of formal credentials recognised by host country certification bodies. Market embeddedness challenges include resource constraints limiting technology investment, customer digital literacy mismatches, and pressures from existing businesses.

While these challenges initially act as constraints, they create an environment that acts as a critical trigger for immigrant entrepreneurs in their journey. As these challenges are addressed, they may encourage adaptive learning and resilience building by compelling immigrant entrepreneurs to experiment, learn from errors, and creatively reconfigure limited resources to meet new technological demands. This finding aligns with the bricolage and constraint-based innovation literature. It explains how entrepreneurs make adjustments with the available resources and improvise under capacity constraints rather than waiting for ideal conditions (Baker and Nelson 2005; Senyard et al. 2014). It also means that challenges do not need to disappear. However, if entrepreneurs have a minimal level of understanding of digital literacy, limited access to networks, and a certain degree of institutional tolerance to act, they can convert these challenges into productive inputs. Under such boundary conditions, constraints may encourage experimentation, learning, and adaptive recombination of resources. However, if these minimum capabilities are absent (complete digital illiteracy, no access to collaborate), then the challenges remain primarily debilitating rather than enabling.

Thus, the findings highlight both the inhibiting and enabling nature of these challenges. It shows that necessity-driven innovation emerges more likely when foundational skills and support structure exists, without which constraints continue to reinforce disadvantage rather than transformation. It aligns with the dynamic capabilities theory, which suggests that crises and constraints stimulate the sensing of alternative opportunities and the development of new routines. For instance, entrepreneurs who have repeatedly faced failures due to technical or cost barriers often developed low-cost, hybrid digital approaches. They could integrate social media platforms and online booking systems to market themselves and manage operations.

Such adaptive responses are also visible in how immigrant entrepreneurs overcome these challenges by mobilising collaborative networks. Those facing institutional barriers invest more in digital training and educational programmes, whereas those facing market barriers invest in increasing collaborative networks (Elia et al. 2020). This path highlights that these challenges trigger heightened sensing of implementation barriers, and collaborative networks help in seizing alternative opportunities. It subsequently helps them create tailored metrics to evaluate the success of their digital implementation, supporting the broader digital transformation process. Thus, the adoption challenges, although having polarity, coexist

with enabling forces and produce adaptive capacity. In their journey, immigrant entrepreneurs use their learned resilience to develop tailored metrics for evaluating digital innovation success. This way, they reinforce their transformation cycle from adversity to innovation. This path aligns with the past literature, wherein it is observed that those who participate in collaborative innovation networks adapt better to the adoption challenges and develop context-specific ways to evaluate their progress.

5.1.4 Path 4. Knowledge Building → Collaborative Networks → Digital Skills Training and Continuous Learning → Future Plans for Digital Innovation

This path demonstrates social embeddedness as infrastructure for sustained capability development. This path highlights that existing knowledge fosters a culture of continuous learning and expertise development that leads to structured skill development and fosters innovation. It further highlights how knowledge and skills strengthen partnerships and ecosystems for shared innovation. Collaborative networks function as informal learning ecosystems that compensate for their limited access to formal institutional training. The continuous learning from these networks helps them track evolving digital trends and adapt strategies iteratively.

Thus, tracking evolving trends helps in sensing opportunities in the environment. Moreover, it is also observed that those who used collaborative innovation-led systematic digital skills development often had informed and well-curated long-term digital strategies. This skill development helps in seizing opportunities from the environment. Thus, the path reiterates that immigrant entrepreneurs who engage in collaborative, continuous digital skills training are more likely to develop robust, future-oriented digital innovation strategies, transforming initial knowledge into strategic capabilities.

The four paths collectively suggest that digital innovation may enhance immigrant entrepreneurs' capabilities across embeddedness dimensions. Firstly, digitalisation helps remove geographical limitations in peer learning and building social networks, allowing them to circumvent institutional barriers. Then, structural barriers intensify the reliance on these social networks, accelerating cultural intelligence development and fostering continuous learning. Dynamic capabilities help in sensing opportunities, seizing them, and transforming the embeddedness from static constraints to dynamic resources.

The findings also reinforce that the barriers and negative linkages do not just act as constraints in the immigrant entrepreneurial journey. They act as a stimulus to compel learning, innovation, and collaboration. By addressing these challenges, immigrant entrepreneurs reinterpret challenges as opportunities for capability development. It reaffirms the study's core argument that digital innovation is

interpreted by experts as enabling embeddedness to shift from a static constraint toward a dynamic capability system.

5.2 Validation of Different Linkages in the Model

The different paths identified in the model are validated through expert opinions (Appendix F). The experts were asked to rate the strength of the identified linkage from 0 to 5. Since the rating is ordinal, the study uses median and Inter-Quartile Range (IQR) to assess dispersion in rating and judgment stability.

The observed median values for expert opinion for the identified linkages suggest consistent expert agreement regarding the strength and logical coherence of the structural paths. Similarly, the relatively low interquartile ranges across expert responses indicate stability in expert assessments. For instance, the relationships between measuring the success of digital innovation and future plans for digital innovation (F9–F12) and between Future Plans for Digital Innovation and Resilience and Crisis Management (F12–F15) have a median value of 4 and an IQR of 0. It indicates that the assessment of these relationships has a very high stability among the experts. For example, experts noted that immigrant entrepreneurs who measure and observe the success of digitalization with metrics such as improved bookings, customer retention, or operational efficiency are more likely to formulate the future digitalization plans. Similarly, the relationships between Impact of Digital Tools on Overcoming Barriers and Integrated Sustainability Practices (F3–F4), Challenges in Adopting Digital Tools and Measuring the Success of Digital Innovation (F10–F9), and Sustainability-Driven Value Proposition and Digital Transformation for Sustainovation (F16–F17) show a high agreement among experts with a median of 4 and an IQR of 0.75. The relationships associated with the existing digital knowledge, collaborative networks, and future digital plans received the strongest expert support.

However, there are relationships where less consensus is observed among the experts, and the relationship judgement is not that stable. For instance, relationships between collaborative innovation networks and continuous learning (F14–F11), digital skills training and cultural adaptability (F11–F13), adoption and use of digital tools and overcoming barriers (F2–F3), and digital financial management and regulatory adaptation (F7–F8) have an IQR of 2. One possible reason for this dispersion could be the contextual nature of these relationships, which may be influenced by differences in destination settings, regulatory conditions, resource accessibility, and levels of digital readiness among immigrant entrepreneurs. These variations in the identified relationships align more with heterogeneous and context-dependent tourism entrepreneurship in a real-world scenario. For example, expert perception

on the relationship between adoption and use of digital tools and overcoming barriers may vary because of their assessment of how much digitalisation can help overcome barriers. Some experts perceived that digitalisation can help significantly overcome market access, visibility, and operational flexibility. However, others perceived that structural issues such as institutional exclusion, financial limitations, and regulatory constraints might remain despite the adoption of digital tools.

6 Conclusion and Study Implications

This study extends MET by reconceptualising structural embeddedness as a condition that needs to be strategically reconfigured. Past studies have highlighted the inhibiting role of market, institutional, and social embeddedness on immigrants' entrepreneurial intentions. This study is among the first to interpret how digital capabilities may assist immigrant entrepreneurs in reconfiguring these constraints into potential opportunities. The TISM-P-based hierarchical model shows that social and market embeddedness are much more responsive to the digital capabilities, while institutional embeddedness takes more effort to be reconfigured. This differential effect was interpreted to emerge because digital capabilities have a much larger and visible impact on visibility, network expansion, and customer interaction, while institutional constraints remain governed by regulatory and bureaucratic mechanisms that are less amenable to digital mediation.

Furthermore, the findings reveal the boundary conditions under which the intended reconfiguration fails. It may become less effective when foundational digital competencies are weak, when implementation barriers outweigh the benefits of capabilities, or when learning processes are discontinuous. These are also the inhibiting influences in the hierarchical model that can be identified through negative polarity. Under such conditions, embeddedness structures may continue to operate as constraints rather than evolving into resources. The findings also reveal that digital adoption may have inhibiting effects, including administrative overload, technological redundancy, and increased exposure to platform dependency risks.

The modelling also allows for the identification of four critical paths in the study through which entrepreneurs may reconfigure to achieve sustainability. These paths represent the most influential relational configurations identified through expert evaluation rather than illustrative trajectories selected for exposition. Each path reflects dominant influence flows linking foundational drivers, mediating mechanisms, and sustainability outcomes.

The study also offers practical implications based on the relationships identified and hierarchy in the model. The study differentiates these implications based on the stakeholder role. For incubators and entrepreneurial agencies, they must invest in

building foundational digital knowledge through sector-specific, tourism-oriented training programs covering reservation systems, experience design platforms, and location-based marketing tools. It is directly concerned with the base-level drivers in the model. Another implication is the requirement of continuous investment in capability development that guards against technological obsolescence, which is one of the negative drivers in the model. It renders the existing foundational knowledge redundant. Peer learning structures and collaborative innovation programs may help convert individual competencies into relational capabilities.

For DMOs, the hierarchical model offers distinct strategic actions. As institutional embeddedness is less responsive to reconfiguration by digital capabilities, it highlights the need for external support to immigrant entrepreneurs to bridge the gap. Multilingual digital compliance portals, automated documentation workflows, and advisory desks reduce the administrative burden that the model identifies as an inhibiting influence. They could also facilitate access to collaborative networks and co-creation platforms to further strengthen the social embeddedness pathways. This may assist immigrant entrepreneurs to convert cultural knowledge into marketable, differentiated offerings rather than remaining peripheral to mainstream destination ecosystems.

For technology and digital platform partners, the hierarchical model highlights specific negative-polarity risks that these actors are uniquely positioned to mitigate. Structural vulnerabilities such as platform dependency, pricing volatility, and opaque visibility algorithms may emerge if digital market access is not accompanied by adequate safeguards. To address these concerns, partners can provide a transparent ranking mechanism, multi-platform integration tools, adaptive pricing analytics tied to demand signals, and sustainability recognition features that strengthen market positioning without increasing dependency. Although these actions will not directly contribute to sustainability, they can reduce the inhibiting influences identified in the hierarchical model.

Thus, the study concludes that digital capabilities can assist in reconfiguring embeddedness, provided there are foundational capabilities, developed ecosystem conditions, and the active management of inhibiting influences.

Conflict of interest: The authors report there are no competing interests to declare.

Appendix A: Initially Identified 32 Factors

Factors	Factors
Basic digital literacy*	High cost of digital tools**
Advanced digital platform skills*	Lack of technical support**
Willingness to experiment with new tech*	Fear of technology/security concerns**

(continued)

Factors	Factors
Level of digital tool integration**	Formal digital training programs*
Use of digital tools for market access*	Informal peer-to-peer learning**
Digital tools for reducing marketing costs**	Plans for adopting emerging technologies*
Adoption of digital payment systems*	Strategy for digital business model evolution**
Use of financial software for management*	Use of social media for community building*
Digital tools for regulatory compliance*	Participation in local online business networks**
Awareness of digital legal requirements**	Ability to navigate cultural nuances in host country*
Tracking online performance metrics*	Leveraging ethnic networks for digital advantage**
Measuring ROI of digital investments*	Collaboration with local tech startups*
Implementation of digital green practices*	Participation in cross-border digital networks**
Promotion of local and sustainable suppliers online*	Digital communication to build customer trust**
Communicating sustainability value to customers*	Use of CRM for personalized customer service*
Use of digital tools for crisis communication	Digital pivoting for business model resilience**

Note: In random order. *Means factor identified from LR. **Means factor identified after expert interaction.

We identified the thirty-two factors mentioned above from the literature review and informal discussion with the immigrant entrepreneurs. Then each of the authors individually clubbed them into common categories. Once they had prepared the combined codes, a code comparison query was run on NVivo to identify the similarity between the codes. The initial results showed a Kappa value for overall codes to be 0.52. Then, for the codes that had a higher level of disagreements, we discussed identifying the issues for disagreement and rectifying the common coding. We also took the assistance of one colleague, wherein a consensus was not reached. Finally, the overall Kappa value came out to be 0.81, and for the individual codes, the highest disagreement value was around 0.091.

Appendix B: Final Seventeen Factors

S. No.	Identified factors	Merged common factor
1	Basic digital literacy	Knowledge and skills in digital tools
2	Advanced digital platform skills	
3	Willingness to experiment with new tech	Adoption and use of digital tools
4	Level of digital tool integration	
5	Use of digital tools for market access	Impact of digital tools on overcoming barriers
6	Digital tools for reducing marketing costs	
7	Implementation of digital green practices	Integrated sustainability practices
8	Promotion of local and sustainable suppliers online	

(continued)

S. No.	Identified factors	Merged common factor
9	Digital communication to build customer trust	Customer engagement and digital personalisation
10	Use of CRM for personalized customer service	
11	Use of social media for community building	Community engagement and local networking
12	Participation in local online business networks	
13	Adoption of digital payment systems	Digital strategies for financial management
14	Use of financial software for management	
15	Digital tools for regulatory compliance	Regulatory and legal digital adaptation
16	Awareness of digital legal requirements	
17	Tracking online performance metrics	Measuring the success of digital innovation
18	Measuring ROI of digital investments	
19	High cost of digital tools	Challenges in adopting digital tools
20	Lack of technical support	
21	Fear of technology/security concerns	
22	Formal digital training programs	Digital skills training and continuous learning
23	Informal peer-to-peer learning	
24	Plans for adopting emerging technologies	Future plans for digital innovation
25	Strategies for digital business model innovation	
26	Ability to navigate cultural nuances in host country	Cultural intelligence and adaptability
27	Leveraging ethnic networks for digital advantage	
28	Collaboration with local tech startups	Collaborative innovation networks
29	Participation in cross-border digital networks	
30	Use of digital tools for crisis communication	Resilience and crisis management
31	Digital pivoting for business model resilience	
32	Communicating sustainability value to customers	Sustainability-driven value proposition
Self-coded by authors collectively		Digital transformation for sustainovation

Appendix C: Operational Definition of Finalized Factors

S. No.	Factor name	Functional role	Definition in the study's context
1	Knowledge and skills in digital tools	Enabling capability	The foundational (basic) knowledge and technical ability required to understand, operate, and apply digital technologies in business activities.

(continued)

S. No.	Factor name	Functional role	Definition in the study's context
2	Adoption and use of digital tools	Enabling capability	The extent to which digital tools are integrated into day-to-day business processes and decision-making activities.
3	Impact of digital tools on overcoming barriers	Strategic transitional condition	The perceived impact of digital technologies in reducing structural, market, or resource constraints faced by immigrant entrepreneurs.
4	Integrated sustainability practices	Strategic transitional condition	The incorporation of environmental, social, and economic sustainability considerations into business operations and value creation processes. It includes practices such as – participation in destination preservation and development programs – collaboration with local communities and suppliers to retain economic value within the destination – use of digital platforms to promote locally rooted cultural experiences – alignment with destination-level environmental or socio-cultural standards
5	Customer engagement and digital personalisation	Capacity-building/relational mechanism	The use of digital platforms to engage with customers, customise offerings, and strengthen experience-based value propositions.
6	Community engagement and local networking	Capacity-building/relational mechanism	The ability of entrepreneurs to build and maintain linkages with host-community actors, institutions, and stakeholders.
7	Digital strategies for financial management	Strategic transitional condition	The use of digital tools and platforms to manage financial planning, transactions, pricing, budgeting, revenue tracking, and resource allocation within the business.
8	Regulatory and legal digital adaptation	Strategic transitional condition	The use of digital systems and platforms to meet regulatory, compliance, licensing, and documentation requirements.
9	Measuring the success of digital innovation	Strategic transitional condition	The processes and indicators used to assess the outcomes and effectiveness of digital initiatives in business performance and stakeholder value.
10	Challenges in adopting digital tools	Inhibiting condition	Constraints such as cost, skills gaps, infrastructure limitations, and learning barriers restrict effective digital adoption.

(continued)

S. No.	Factor name	Functional role	Definition in the study's context
11	Digital skills training and continuous learning	Enabling capability	Continuous efforts to upgrade and renew digital competencies in response to technological and market changes.
12	Future plans for digital innovation	Strategic transitional condition	Strategic intent and commitment towards expanding or deepening digitalization efforts in the future.
13	Cultural intelligence and adaptability	Capacity-building/relational mechanism	The ability to understand, interpret, and act appropriately across cultural contexts, and to convert cultural knowledge into business value.
14	Collaborative innovation networks	Capacity-building/relational mechanism	Participation in networks that support knowledge sharing, resource exchange, problem-solving, and joint innovation.
15	Resilience and crisis management	Strategic outcome	The capacity to respond to shocks or crises to stabilise operations, sustain revenue, and reorganise resources.
16	Sustainability-driven value proposition	Strategic outcome	Positioning the business around sustainability-oriented offerings that create legitimacy, trust, and differentiation in the market.
17	Digital transformation for sustainovation	Strategic outcome	The perceived integration of digitalisation and sustainability practices into broader organisational adaptation and innovation processes.

Appendix D: Details of Experts in the TISM Process

S. No.	Role	Category	Core expertise	Exp. (in years)
E1	Tour Operator, Founder	Immigrant entrepreneur	Digital marketing	08
E2	Cultural Heritage Homestay, Owner	Immigrant entrepreneur	Heritage entrepreneurship	12
E3	Senior Manager, Destination Marketing Organization	Tourism industry professional	Promotion and market access	10
E4	Regional Tourism Board, Policy Officer	Tourism industry professional	Governance, public relations	09

(continued)

S. No.	Role	Category	Core expertise	Exp. (in years)
E5	Sustainability Consultant	Sustainability specialist	ESG strategy, circular supply chains	11
E6	Researcher, Sustainable Tourism	Sustainability specialist	Sustainable innovation	07
E7	Digital Transformation Advisor	Digital innovation consultant	AI adoption in tourism and hospitality	10
E8	Tech Startup Founder	Digital innovation consultant	Data analytics, digital experience design	06
E9	Technology Integration Specialist	Digital innovation consultant	IoT, smart destinations	15
E10	Cross-Border Tourism Platform Co-Founder	Immigrant entrepreneur	Platform economy	09
E11	Travel Aggregator, Marketing Director	Tourism industry professional	Market development	14
E12	AI Systems Architect	Digital innovation consultant	Automation, service innovation	06
E13	Researcher, Sustainable Tourism	Sustainability specialist	Social innovation, green entrepreneurship	06
E14	Cultural Experience Tours, Founder	Immigrant entrepreneur	Cross-cultural innovation	07

Appendix E: Consensus-Building Rounds

Stage	Output	% Relationships meeting threshold	Action taken
Round 1	Initial pairwise relationships and polarity assessments	48 % ≥ 60 %	Relationships below 60 % flagged for clarification
Round 2	Clarification and explanation exchange	28 % between 60–75 %	Additional discussion and sequential re-assessment
Round 3	Final consensus structure	100 % ≥ 75 %	Relationships retained and polarity confirmed

Appendix F: Validation of Identified Linkages

Relationship	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	Mean	Median	IQR
F1–F14	4	3	5	3	4	5	4	4	4	3	3	5	3	3	3.785714	4	1
F1–F2	4	3	5	5	4	4	5	3	5	5	4	4	3	5	4.214286	4	1
F14–F10	4	5	4	4	5	3	5	3	4	4	3	3	4	5	4	4	1.5
F14–F11	3	4	3	5	3	5	4	4	5	3	3	5	5	5	4.071429	4	2
F14–F13	4	4	3	3	4	5	5	3	3	3	3	3	5	3	3.642857	3	1
F14–F15	4	4	5	5	4	5	5	5	4	4	5	4	4	3	4.357143	4	1
F10–F11	3	4	3	5	5	5	3	5	4	3	3	4	4	3	3.857143	4	1.75
F10–F2	3	5	3	3	4	4	5	5	4	3	5	4	3	4	3.928571	4	1.75
F10–F9	4	4	3	3	5	5	4	3	4	4	4	5	4	3	3.928571	4	0.75
F11–F2	3	3	5	3	5	3	3	4	5	3	3	4	5	4	3.785714	3.5	1.75
F11–F10	5	4	4	4	3	4	3	4	4	3	3	3	5	5	3.857143	4	1
F11–F12	3	3	5	5	4	4	5	3	4	5	3	3	4	4	3.928571	4	1.75
F11–F13	3	3	4	3	5	4	3	3	5	5	5	5	3	4	3.928571	4	2
F2–F3	3	5	5	5	3	3	3	4	5	5	3	3	5	3	3.928571	3.5	2
F3–F4	4	3	4	4	4	4	4	4	4	3	4	3	3	4	3.714286	4	0.75
F13–F4	3	3	3	4	4	3	3	4	5	3	5	5	4	5	3.857143	4	1.75
F4–F5	5	3	4	3	3	4	3	4	5	4	5	3	4	5	3.928571	4	1.75
F5–F6	3	5	3	3	5	4	3	4	4	4	3	5	4	3	3.785714	4	1
F6–F7	5	5	3	3	3	3	4	4	4	4	3	4	4	5	3.857143	4	1
F7–F8	3	4	3	5	5	3	5	5	3	3	4	4	5	5	4.071429	4	2
F8–F9	3	4	5	4	4	5	5	3	3	4	4	3	5	4	4	4	1.5
F9–F12	5	4	5	4	4	3	4	4	5	3	4	4	4	3	4	4	0
F12–F15	4	4	4	3	4	5	4	3	4	4	5	3	5	4	4	4	0
F15–F16	4	3	4	4	3	5	4	5	5	5	4	4	3	3	4	4	1.5
F16–F17	3	4	4	4	4	5	4	5	4	3	5	3	4	5	4.071429	4	0.75

Appendix G: Central Relationships with Direction, Polarity, and Influence Type

From → To	Direction	Polarity	Influence type
F1 knowledge and skills in digital tools → F14 collaborative innovation networks	Forward	Positive	Foundational driver → network formation
F1 knowledge and skills in digital tools → F11 digital skills training and continuous learning	Forward	Positive	Foundational driver → learning linkage
F11 digital skills training and continuous learning → F2 adoption and use of digital tools	Forward	Positive	Learning linkage → adoption enabler

(continued)

From → To	Direction	Polarity	Influence type
F10 challenges in adopting digital tools → F2 adoption and use of digital tools	Forward	Negative	Constraint driver → adoption inhibitor
F2 adoption and use of digital tools → F13 integrated sustainability practices	Forward	Positive	Adoption linkage → sustainability integration
F11 digital skills training and continuous learning → F13 integrated sustainability practices	Forward	Positive	Learning linkage → sustainability alignment
F10 challenges in adopting digital tools → F9 regulatory and legal digital adaptation	Forward	Negative	Constraint driver → compliance barrier
F13 integrated sustainability practices → F12 measuring the success of digital innovation	Forward	Positive	Linking capability → evaluation structure
F13 integrated sustainability practices → F15 future plans for digital innovation	Forward	Positive	Linking capability → strategic planning

Appendix H: Reachability Matrix

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Driving
F1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	16
F2	0	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	12
F3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
F4	0	0	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	11
F5	0	0	1	0	1	1	1	1	1	0	0	1	0	0	1	1	1	10
F6	0	0	1	0	0	1	1	1	1	0	0	1	0	0	1	1	1	9
F7	0	0	1	0	0	0	1	1	1	0	0	1	0	0	1	1	1	8
F8	0	0	1	0	0	0	0	1	1	0	0	1	0	0	1	1	1	7
F9	0	0	1	0	0	0	0	0	1	0	0	1	0	0	1	1	1	6
F10	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	14
F11	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	14
F12	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	1	5
F13	0	0	1	1	1	1	1	1	1	0	0	1	1	0	1	1	1	12
F14	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
F15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	4
F16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	4
F17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3
Dependence	1	5	17	7	8	9	10	11	12	4	4	13	2	2	16	15	16	

Appendix I: Iteration Matrix

	Reachability set	Antecedent set	Intersection	
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17	1		R1
2	2, 3, 4, 5, 6, 7, 8, 9, 12, 15, 16, 17	1, 2, 10, 11, 14		
3	3, 4, 5, 6, 7, 8, 9, 12, 15, 16, 17	1, 2, 3, 10, 11, 14		
4	4, 5, 6, 7, 8, 9, 12, 15, 16, 17	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6, 7, 8, 9, 12, 15, 16, 17	1, 2, 3, 4, 5, 10, 11, 13, 14		
6	6, 7, 8, 9, 12, 15, 16, 17	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
7	7, 8, 9, 12, 15, 16, 17	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
8	8, 9, 12, 15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14		
9	9, 12, 15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14		
10	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 17	1, 10, 11, 14		
11	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 17	1, 10, 11, 14		
12	12, 15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14		
13	4, 5, 6, 7, 8, 9, 12, 13, 15, 16, 17	13, 14		
14	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	1, 14		
15	15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15		
16	16, 17	1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 10, 11, 12, 13, 14, 15, 16		
17	17	1, 2–17	17	

	Reachability set	Antecedent set	Intersection	
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16	1		R2
2	2, 3, 4, 5, 6, 7, 8, 9, 12, 15, 16	1, 2, 10, 11, 14		
3	3, 4, 5, 6, 7, 8, 9, 12, 15, 16	1, 2, 3, 10, 11, 14		
4	4, 5, 6, 7, 8, 9, 12, 15, 16	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6, 7, 8, 9, 12, 15, 16	1, 2, 3, 4, 5, 10, 11, 13, 14		
6	6, 7, 8, 9, 12, 15, 16	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
7	7, 8, 9, 12, 15, 16	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
8	8, 912, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14		
9	9, 12, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14		
10	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16	1, 10, 11, 14		
11	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16	1, 10, 11, 14		
12	12, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14		
13	4, 5, 6, 7, 8, 9, 12, 13, 15, 16	13, 14		
14	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 14		
15	15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15		
16	16	1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 10, 11, 12, 13, 14, 15, 16	16	

(continued)

	Reachability set	Antecedent set	Intersection	
	Reachability set	**Antecedent set**	**Intersection**	
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	1		R3
2	2, 3, 4, 5, 6, 7, 8, 9, 12, 15	1, 2, 10, 11, 14		
3	3, 4, 5, 6, 7, 8, 9, 12, 15	1, 2, 3, 10, 11, 14		
4	4, 5, 6, 7, 8, 9, 12, 15	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6, 7, 8, 9, 12, 15	1, 2, 3, 4, 5, 10, 11, 13, 14		
6	6, 7, 8, 9, 12, 15	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
7	7, 8, 9, 12, 15	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
8	8, 9, 12, 15	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14		
9	9, 12, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14		
10	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15	1, 10, 11, 14		
11	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15	1, 10, 11, 14		
12	12, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14		
13	4, 5, 6, 7, 8, 9, 12, 13, 15	13, 14		
14	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 14		
15	15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	15	

	Reachability set	Antecedent set	Intersection	
	Reachability set	**Antecedent set**	**Intersection**	
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14	1		R4
2	2, 3, 4, 5, 6, 7, 8, 9, 12	1, 2, 10, 11, 14		
3	3, 4, 5, 6, 7, 8, 9, 12	1, 2, 3, 10, 11, 14		
4	4, 5, 6, 7, 8, 9, 12	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6, 7, 8, 9, 12	1, 2, 3, 4, 5, 10, 11, 13, 14		
6	6, 7, 8, 9, 12	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
7	7, 8, 9, 12	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
8	8, 9, 12	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14		
9	9, 12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14		
10	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 10, 11, 14		
11	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 10, 11, 14		
12	12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	12	
13	4, 5, 6, 7, 8, 9, 12, 13	13, 14		
14	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 14		

	Reachability set	Antecedent set	Intersection	
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14	1		R5
2	2, 3, 4, 5, 6, 7, 8, 9	1, 2, 10, 11, 14		
3	3, 4, 5, 6, 7, 8, 9	1, 2, 3, 10, 11, 14		
4	4, 5, 6, 7, 8, 9	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6, 7, 8, 9	1, 2, 3, 4, 5, 10, 11, 13, 14		
6	6, 7, 8, 9	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		

(continued)

	Reachability set	Antecedent set	Intersection	
7	7, 8, 9	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
8	8, 9	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14		
9	9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14	9	
10	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 10, 11, 14		
11	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	1, 10, 11, 14		
13	4, 5, 6, 7, 8, 9, 13	13, 14		
14	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14	1, 14		

	Reachability set	Antecedent set	Intersection	
1	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 14	1		R6
2	2, 3, 4, 5, 6, 7, 8	1, 2, 10, 11, 14		
3	3, 4, 5, 6, 7, 8	1, 2, 3, 10, 11, 14		
4	4, 5, 6, 7, 8	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6, 7, 8	1, 2, 3, 4, 5, 10, 11, 13, 14		
6	6, 7, 8	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
7	7, 8	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
8	8	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14	8	
10	2, 3, 4, 5, 6, 7, 8, 10, 11	1, 10, 11, 14		
11	2, 3, 4, 5, 6, 7, 8, 10, 11	1, 10, 11, 14		
13	4, 5, 6, 7, 8, 13	13, 14		
14	2, 3, 4, 5, 6, 7, 8, 10, 11, 13, 14	1, 14		

	Reachability set	Antecedent set	Intersection	
1	1, 2, 3, 4, 5, 6, 7, 10, 11, 14	1		R7
2	2, 3, 4, 5, 6, 7	1, 2, 10, 11, 14		
3	3, 4, 5, 6, 7	1, 2, 3, 10, 11, 14		
4	4, 5, 6, 7	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6, 7	1, 2, 3, 4, 5, 10, 11, 13, 14		
6	6, 7	1, 2, 3, 4, 5, 6, 10, 11, 13, 14		
7	7	1, 2, 3, 4, 5, 6, 7, 10, 11, 13, 14	7	
10	2, 3, 4, 5, 6, 7, 10, 11	1, 10, 11, 14		
11	2, 3, 4, 5, 6, 7, 10, 11	1, 10, 11, 14		
13	4, 5, 6, 7, 13	13, 14		
14	2, 3, 4, 5, 6, 7, 10, 11, 13, 14	1, 14		

	Reachability set	Antecedent set	Intersection	
1	1, 2, 3, 4, 5, 6, 10, 11, 14	1		R8
2	2, 3, 4, 5, 6	1, 2, 10, 11, 14		
3	3, 4, 5, 6	1, 2, 3, 10, 11, 14		
4	4, 5, 6	1, 2, 3, 4, 10, 11, 13, 14, 15		
5	5, 6	1, 2, 3, 4, 5, 10, 11, 13, 14		

(continued)

	Reachability set	Antecedent set	Intersection
6	6	1, 2, 3, 4, 5, 6, 10, 11, 13, 14	6
10	2, 3, 4, 5, 6, 10, 11	1, 10, 11, 14	
11	2, 3, 4, 5, 6, 10, 11	1, 10, 11, 14	
13	4, 5, 6, 13	13, 14	
14	2, 3, 4, 5, 6, 10, 11, 13, 14	1, 14	

	Reachability set	Antecedent set	Intersection
1	1, 2, 3, 4, 5, 10, 11, 14	1	R9
2	2, 3, 4, 5	1, 2, 10, 11, 14	
3	3, 4, 5	1, 2, 3, 10, 11, 14	
4	4, 5	1, 2, 3, 4, 10, 11, 13, 14, 15	
5	5	1, 2, 3, 4, 5, 10, 11, 13, 14	5
10	2, 3, 4, 5, 10, 11	1, 10, 11, 14	
11	2, 3, 4, 5, 10, 11	1, 10, 11, 14	
13	4, 5, 13	13, 14	
14	2, 3, 4, 5, 10, 11, 13, 14	1, 14	

	Reachability set	Antecedent set	Intersection
1	1, 2, 3, 4, 10, 11, 14	1	R10
2	2, 3, 4	1, 2, 10, 11, 14	
3	3, 4	1, 2, 3, 10, 11, 14	
4	4	1, 2, 3, 4, 10, 11, 13, 14, 15	4
10	2, 3, 4, 10, 11	1, 10, 11, 14	
11	2, 3, 4, 10, 11	1, 10, 11, 14	
13	4, 13	13, 14	
14	2, 3, 4, 10, 11, 13, 14	1, 14	

	Reachability set	Antecedent set	Intersection
1	1, 2, 3, 10, 11, 14	1	R11
2	2, 3	1, 2, 10, 11, 14	
3	3	1, 2, 3, 10, 11, 14	3
10	2, 3, 10, 11	1, 10, 11, 14	
11	2, 3, 10, 11	1, 10, 11, 14	
13	13	13, 14	13
14	2, 3, 10, 11, 13, 14	1, 14	

	Reachability set	Antecedent set	Intersection
1	1, 2, 10, 11, 14	1	R12
2	2	1, 2, 10, 11, 14	2
10	2, 10, 11	1, 10, 11, 14	
11	2, 10, 11	1, 10, 11, 14	
14	2, 10, 11, 14	1, 14	

(continued)

	Reachability set	Antecedent set	Intersection	
	Reachability set	**Antecedent set**	**Intersection**	
1	1, 10, 11, 14	1		R13
10	10, 11	1, 10, 11, 14	10, 11	
11	10, 11	1, 10, 11, 14	10, 11	
14	10, 11, 14	1, 14		
	Reachability set	**Antecedent set**	**Intersection**	
1	1, 14	1		R14
14	14	1, 14	14	
	Reachability set	**Antecedent set**	**Intersection**	
1	1	1	1	R15

Appendix J: Driving and Dependence Level

Code	Dependence level	Driving power
1	1	16
2	5	12
3	17	1
4	7	11
5	8	10
6	9	9
7	10	8
8	11	7
9	12	6
10	4	14
11	4	14
12	13	5
13	2	12
14	2	16
15	16	4
16	15	4
17	16	3

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