Exploring the Relationship Dynamics in Entrepreneurial Ecosystems and Their Impact upon Innovation

Damaris Chieregato Vicentin
Postdoctoral Researcher, School of Applied Sciences[a], damarisv@unicamp.br

Gustavo Hermínio Salati Marcondes de Moraes
Associate Professor, School of Applied Sciences[a]; Guest Researcher, Institute for Statistical Studies and Economics of Knowledge (ISSEK)[b], salati@unicamp.br

Nágela Bianca do Prado
PhD Applicant, School of Applied Sciences[a], nagelabianca.prado@gmail.com

Bruno Brandão Fischer
Associate Professor, School of Applied Sciences[a]; Guest Researcher, ISSEK[b], bfischer@unicamp.br

Betania Silva Carneiro Campello
Professor, School of Applied Sciences[a], betaniac@unicamp.br

Rosley Anholon
Professor, School of Mechanical Engineering[a], rosley@unicamp.br

[a] University of Campinas (UNICAMP), Pedro Zaccaria street, 1300, Limeira – SP 13484-350, Brazil
[b] National Research University Higher School of Economics, 11, Myasnitskaya str., Moscow 101000, Russian Federation

Abstract

This study investigates how key entrepreneurial ecosystem (EE) factors interact and are reconfigured in response to economic turbulence. Using Russia as a case study, we analyze the systemic dynamics of EE through the lens of the Complex Adaptive Systems (CAS) theory, identifying the most influential factors driving ecosystem resilience. A quantitative approach was employed using the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. Data were collected from highly experienced experts, including academics and market professionals with extensive knowledge of urban EEs in Russia. Their evaluations provided a robust understanding of causal relationships and the adaptability of EE factors under economic instability. The regulatory environment emerged as the primary driver of EE reconfiguration, significantly influencing other factors. Human capital and access to capital were also critical for sustaining entrepreneurship in turbulent contexts, whereas innovation was highly dependent on external conditions rather than acting as an independent driver. These findings highlight the need for adaptive policies to enhance EE resilience, offering a novel methodological framework for understanding EE adaptability in emerging economies.

Keywords: entrepreneurial ecosystems; complex adaptive systems; strategies; complex interaction; human capital; innovation; self-organization: economic turbulence; fuzzy DEMATEL; Russia

Citation: Vicentin D.B., Marcondes de Moraes G.H.S., Bianca do Prado N., Fischer B.B., Campello B.S.C., Anholon R. (2025) Exploring the Relationship Dynamics in Entrepreneurial Ecosystems and Their Impact upon Innovation. *Foresight and STI Governance*, 19(2), pp. 43–53. https://doi.org/10.17323/fstig.2025.25819

Introduction

The concept of an entrepreneurial ecosystem has been widely used to gain a better understanding of the phenomenon of high-growth entrepreneurship, as well as the complex interactions between entrepreneurs and their environments (Vedula, Kim, 2019). The interacting elements of ecosystems encompass systemic factors as well as entrepreneurs, considering the synergy between stakeholders and the institutional aspects that shape the context for entrepreneurial initiatives (Audretsch et al., 2019; Stam, 2015).

The Russian entrepreneurial ecosystem faces unique challenges and opportunities in the global political disputes and the current conflict. In this context, with global turbulence influencing domestic policies and economic structures, innovation plays a key role in economic development (Aeeni, Saeedikiya, 2019; Arici et al., 2024). By using the theoretical framework of entrepreneurial ecosystems to analyze this situation, it is possible to have a profound understanding of future directions in the face of the complexities and uncertainties experienced by companies (Altshuller, 2017; Ansell et al., 2017; Brondoni, 2022).

With regard to complexity, Complex Adaptive Systems (CAS) and Entrepreneurial Ecosystems (EE) involve several interacting agents, resulting in unpredictable emergent behaviors due to their extensive interconnectivity (Daniel et al., 2022). Such agents adapt and evolve in response to disturbances, altering their properties or environment. Crises accentuate their interconnectivity and interdependence, accelerating co-evolution and requiring rapid adaptation (Cloutier, Messeghem, 2022; Phillips, Ritala, 2019). Path dependence is crucial in this debate, where initial advantages can result in entrenchment. The CAS theory can address gaps in understanding the development of EE by integrating structural and dynamic approaches.

Yet, empirical evidence in this context remains scarce, and current studies primarily focus on the early stages of EE development (Han et al., 2021; Carter, Pezeshkan, 2023). Hence, although the EE literature encompasses a systemic view of entrepreneurial events, the bulk of contributions remain oriented towards assessments that look into EE dimensions as separate blocks, not as interrelated elements that simultaneously affect and are affected by one another, constantly coevolving and shaping dynamic conditions that enable (or hinder) entrepreneurship. In light of these considerations, this research aims to identify the main factors that impact the development of EE in cities and, more importantly, how these factors relate to each other. Accordingly, our research question can be stated as follows: How do key entrepreneurial ecosystem factors interact and reconfigure in contexts of economic turbulence? This question emphasizes the systemic nature of EE, shifting the focus from individual components to their relational dynamics.

Our empirical setting involves the case of Russia. The analysis conducted by Shirokova et al. (2022) reveals that, notwithstanding the present challenges, the Russian milieu offers distinct opportunities for entrepreneurship research. This underscores the necessity of adopting a novel approach that delves into local specificities, thereby enhancing the applicability of EE on a global scale. Our analytical approach relies on the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method based on primary data collection with 25 EE experts in this country.

Theoretical Background

Entrepreneurial Ecosystems Factors

Isenberg (2010) underscores the need for solutions that originate locally and are tailored to the specific conditions of well-known EEs. The EE is seen as a dynamic community comprising interdependent actors and systemic contexts, emphasizing both the contextual realm and individual decision-making (Audretsch et al., 2019). Therefore, the EE differs across regions and entrepreneurial stakeholder groups, leading to the formulation of hypotheses about the perceived robustness of sustainable and resilient EE (Spigel, Harrison, 2018). The significance of adapting the development of EEs to local conditions is highlighted, reinforcing the multi-scalar and multi-actor nature of these systems (Brown Mason, 2017).

As described by Stam and van de Ven (2021), the factors of the EE consist of six pivotal pillars essential for the development and sustainability of an EE: regulatory environment, infrastructure, market, innovation, access to capital, human capital, and entrepreneurial culture. The regulatory environment, influenced by legal and political forces, plays a central role in the development of the EE, impacting marketing strategies and presenting challenges and opportunities for entrepreneurs (Zhao et al., 2023). Beyond physical conditions, the infrastructure includes digital assets and various amenities that foster an environment conducive to entrepreneurial activities (Audretsch, Belitski, 2017; Stam, van de Ven, 2021). Market dynamics, driven by potential demand for innovative products or services, require strategic market direction for entrepreneurial success (Stam, 2015; Zhao et al., 2023).

Innovation, involving the proactive generation and implementation of new ideas, processes, and collaborations, is essential for nurturing nascent firms and fostering alliances within the EE (Kuratko et al., 2017). Access to capital, including human, social, and financial assets influenced by entrepreneurial decisions, is critical for sustained entrepreneurship, emphasizing reliance on personal financial resources and substantial financial backing for development (Zhao et al., 2023). Human capital, providing intellectual support and entrepreneurial knowledge closely linked to innovation, is an essential contributor to entrepreneurial activities (Stam, van de Ven, 2021; Zhao et al., 2023). Lastly, entrepreneurial culture shapes entrepreneurial intentions and perceptions. An entrepreneurial culture is identified as substantial for EE prosperity, influencing motivation, innovativeness, and risk-taking (Audretsch, Belitski, 2017; Stam, van de Ven, 2021; Vicentin et al., 2024).

Complex Adaptative Systems

The CAS theory was first proposed by Simon (1962), as a reaction to the mechanistic and equilibrium-based view of the world, and was widely adopted by many scholars focused on entrepreneurial systems (van De Ven, 1993; Stam, van de Ven, 2021). By definition, CAS are characterized by numerous interacting elements or agents, resulting in emergent behaviors that are inherently difficult to predict solely by observing individual interactions (Bone, 2016; Fredin, Lidén, 2020). The complexity within these systems arises from their extensive interconnectivity and the challenges associated with predicting their behavior. CAS are large-scale systems whose behaviors can change, evolve, or adapt in response to disturbances, thereby maintaining a stable state by modifying their properties or the surrounding environment (Cloutier, Messeghem, 2022; Phillips, Ritala, 2019).

The complexity of a CAS results from the interaction and interconnectivity between its elements and the environment. Similarly, EEs consist of a diverse set of agents, such as entrepreneurs, investors, educational institutions, government entities, and customers, interacting in complex and interdependent ways (Daniel et al., 2022). In both CAS and EEs, there is no single centralized control mechanism (Aeeni, Saeedikiya, 2019). During a crisis, the interconnectivity, and interdependence of the elements within the system become even more pronounced (Fredin, Lidén, 2020). For instance, economic sanctions, political instability, and changes in government policies directly impact businesses, investors, and consumers within the EE (Khurana et al., 2022).

As highlighted by Roundy et al. (2018), CAS theory can address gaps in the characterization of EE trajectories by integrating structural and dynamic approaches that consider the continuous evolution of sub-ecosystems (Carter, Pezeshkan, 2023; Malecki, 2018). These approaches help one understand how EEs develop through phases of impulse, creation, and structuring, revealing the inherent complexity of their functioning and evolution (Cantner et al., 2021). Nevertheless, these conceptual approaches have not produced empirical evidence of EE framed within the complexity of CAS, and they have mainly concentrated on the early stages of EE development (Han et al., 2021).

In the context of EE, turbulence is defined as a state of tension and transformation and includes a wide range of disruptive events and changes, not just crises but also social, economic, and political transformations. Therefore, the concept of turbulence from the perspective of an EE provides a lens for examining the challenges and opportunities arising in an EE characterized by constant flux. It empowers us to analyze complexity and uncertainty as essential elements in understanding and navigating the collective future of organizations within transforming ecosystems (Aeeni, Saeedikiya, 2019; Arici et al., 2024).

Method

Given the proposed goals, the methodology adopted in this study is based on field research with exploratory, explicative, and propositional research characteristics. This study adopts a quantitative approach utilizing the fuzzy DEMATEL method to systematically identify and analyze the primary factors influencing the development of EEs in urban areas, with a particular focus on the Russian context. Our goal is to elucidate the relationships among these factors, assess their impact, and determine the most influential ones within the dynamic environments of urban EE.

The Russian Context

In the current Russian context, which is marked by significant political changes and international conflicts, unique challenges and opportunities for entrepreneurship arise. Global turbulence dynamics directly impact domestic policies and economic systems, creating an environment where innovation becomes a important driver for economic development (Altshuller, 2017; Ansell et al., 2017; Brondoni, 2022; Nowinska et al., 2025).

Since 2000, Russia has undertaken reforms to strengthen state control and clarify bureaucratic guidelines, often through ambiguous regulations (Yakovlev, 2006). This complex and ever-changing regulatory environment requires entrepreneurs to carefully navigate a series of regulatory and bureaucratic challenges to maintain operational legitimacy.

Simultaneously, the government has encouraged the strengthening of the economy through innovation, aiming to diversify economically and achieve competitive advantages (Shakib et al., 2023). Innovation, substantially supported by public funding, is seen as essential for economic growth, with approximately 70% of this funding coming from the public sector.[1] This focus on innovation has helped Russia improve its position in the Global Competitiveness Index, demonstrating progress in various innovation indicators (Davidson et al., 2018; Shakib et al., 2023).

A literature review by Shirokova et al. (2022) highlights that, despite adversities, the Russian context offers unique opportunities for research and development in entrepreneurship, influenced by geographical, socioeconomic, and ethnic disparities. The need for a

[1] https://www.forbes.ru/tehnologii/366587-put-k-innovaciyam-rossiya-tratit-na-nauku-1-vvp-hvatit-li-etogo, accessed 19.03.2025.

'third wave' of contextualization in entrepreneurship research is emphasized, aiming for a deeper understanding of the local nuances that shape entrepreneurship theories and promoting an expanded dialogue between local and global researchers.

Data Collection

In 2024, an electronic survey (Google Forms) was administered to 25 Russian experts specializing in urban EEs to gather information about the relevance of various factors within these systems in Russian urban contexts.[2] All respondents held postgraduate degrees in entrepreneurship and innovation, and had over six years of practical market experience, ensuring a high level of expertise in both academic and professional domains. Subsequently, the survey introduced seven factors based on the frameworks provided by Stam and van de Ven (2021): regulatory environment, infrastructure, market, access to capital, innovation, human capital, and entrepreneurial culture. The experts then assessed the relevance of these factors to the EE in the cities, completing the statement, "Indicate, in your opinion, the relevance of each of the following elements for a city's entrepreneurial ecosystem." Following this assessment, they analyzed the influence of each factor upon one another in the EE analysis.

Fuzzy DEMATEL Method

The fuzzy logic and DEMATEL models are combined to create a decision-making framework. This model processes the vague assessments of experts into precise values using fuzzy sets for a direct influence matrix. The evaluation starts with experts employing a fuzzy linguistic scale to determine mutual influences between factors, defining causal relationships despite judgment imprecision. Terms such as "None (No), Very Low Influence (VLI), Low Influence (LI), Moderate Influence (MI), High Influence (HI), Very High Influence (VHI)" are employed, with each expert contributing their influence matrix, as demonstrated in Table 1. Also, Figure 1 illustrates the membership functions for fuzzy linguistic terms and their corresponding fuzzy numbers. Consequently, given *n* factors represented by the set $F = \{F_1, F_2,..., F_n\}$ to be evaluated by *l* experts represented by the set $E= \{E_1, E_2,..., E_l\}$, each expert must assess the pairwise influence of factor F_i on factor F_j. This procedure generates an individual direct influence fuzzy matrix $\tilde{Z}_k = [\tilde{z}^k_{ij}]_{n\times}$, in which $\tilde{z}^k_{ij} = (z^k_{ij1}, z^k_{ij2}, z^k_{ij3})$, represents the fuzzy evaluation from an expert *k* (Zhang et al., 2023).

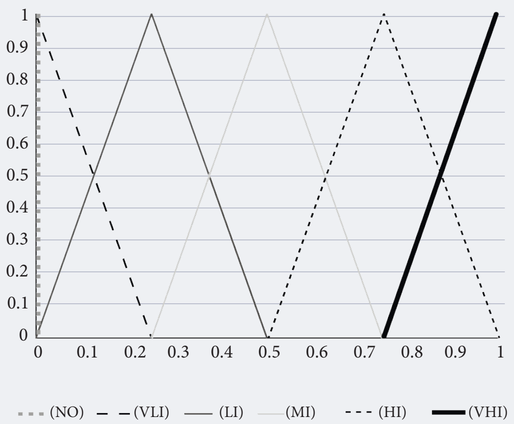
In the second step, we combine the evaluations of experts to create the collective direct-influence fuzzy matrix $\tilde{Z}$. After forming the individual matrices $\tilde{Z}_k$ (k= 1,2,...,*l*), the composite direct-influence fuzzy matrix $\tilde{Z}_k = [\tilde{z}^k_{ij}]_{n\times n}$ is derived by amalgamating the assessments from all experts. Here, $\tilde{z}_{ij}$ is treated as a Triangular Fuzzy Number (TFN) (0,0,0), and $\tilde{z}_{ij}$ is computed as:

Table 1. **Fuzzy Linguistic Terms with Related Fuzzy Numbers**

Linguistic terms	Triangular fuzzy numbers
None 0 (No)	(0, 0, 0)
Very Low Influence (VLI)	(0, 0, 0.25)
Low Influence (LI)	(0, 0.25, 0.5)
Moderate Influence (MI)	(0.25, 0.5, 0.75)
High Influence (HI)	(0.5, 0.75, 1)
Very High Influence (VHI)	(0.75, 1, 1)

Source: adapted from (Singh, Sarkar, 2020; Zhang et al., 2023).

Figure 1. **Membership Function of All Linguistic Terms from Fuzzy DEMATEL**



Source: authors.

$$\tilde{z}_{ij} = (z^k_{ij1}, z^k_{ij2}, z^k_{ij3}) = (1/l)\Sigma^l_{k=1}\tilde{z}^k_{ij} = ((1/l)\Sigma^l_{k=1}z^k_{ij1}, (1/l)\Sigma^l_{k=1}z^k_{ij2}, (1/l)\Sigma^l_{k=1}z^k_{ij3}) \quad (1)$$

In the third step, fuzzy evaluations are defuzzified using the CFCS (Converting Fuzzy Data into Crisp Scores) method to form the crisp direct-influence matrix Z .

In the fourth step, this matrix is used with the DEMATEL method to create the normalized direct-influence matrix X and the total-influence matrix T, which are essential for developing the influential relation map (IRM). The derivation of the normalized direct-influence matrix X is achieved by:

[2] Of the 25 interviewees, 60% were female and 40% were male. On average, experts have 6.9 years of professional experience. Regarding the areas of work, 24% work in information technology, 12% in education, 12% in business and 12% in innovation, and the rest of the sample belongs to the following areas: technology transfer, public policy, electronic device development, energy, entrepreneurship and marketing, project management, accounting, and analytics.

$$X = Z/s,\ s = max(max_{1\le i\le n} \textstyle\sum^{n}_{j=1} z_{ij}, max_{1\le i\le n} \textstyle\sum^{n}_{i=1} z_{ij}), \quad (2)$$

Where all elements are adhered to $0 \le x_{ij} < 1.0 \le \sum^{n}_{j=1} x_{ij} \le 1$ and at least one i such that $i \sum^{n}_{j=1} z_{ij} \le s$.

Subsequently, the total-influence matrix T is computed using:

$$T = X + X^2 + ... + X^h = X (I - X)^{-1}, \quad (3)$$

When h → ∞, in which I is represented as an identity matrix (Rouhani et al., 2013).

Finally, the formulation of an IRM is facilitated with the horizontal axis denoted by ($R + C$) and the vertical axis by ($R - C$), depicting the sum of the rows and columns from the total-influence matrix T, defined respectively by:

$$R = [r_i]_{n\times1} = \textstyle\sum^{n}_{j=1} t_{ij}]_{n\times1},\ C = [c_j]_{1\times n} = \textstyle\sum^{n}_{i=1} t_{ij}]^{T}_{1\times n}, \quad (4)$$

Where, r_i represents the sum of influences a factor F_i exerts on others, while c_j totals the influences received by factor F_j. These calculations determine each factor's centrality as the horizontal axis vector ($R + C$) (named Prominence) and its role as either a net influencer or influenced entity as the vertical axis vector ($R - C$) (named Relation) within the network. These values are visualized in an IRM by plotting the dataset of ($R + C$, $R - C$), which plots the combined influence scores to aid in decision-making.

Steps for Using the Fuzzy DEMATEL Method

The steps to develop the fuzzy DEMATEL method are shown in Figure 2. Initially, data collection was performed with the identification of entrepreneurship ecosystem factors (IT_{ij}) and the opinion of the 25 Russian experts specializing in urban EEs about the relationships and interactions between these factors. After identifying key criteria, the influence matrix is created using linguistic terms and fuzzy numbers to represent the complex relationships as identified by EE experts. Subsequently, each decision-maker attributes scores based on the expert evaluations among the EE factors.

Thereafter, the matrix of relationship influences, designated as "Z", is computed using the CFCS method. The traditional DEMATEL method is then applied in the subsequent steps. Consequently, the "Z" matrix is normalized to form a new matrix "X". Following this, the "T" matrix, which synthesizes the direct influences among the EE factors in the Russian context, is calculated to construct the IRM. The vertical axis vectors "R" and "C", named "Relation", are calculated to visualize and analyze both direct and indirect influences among the factors, thereby facilitating the understanding of the dynamics of the EE in the Russian context.

Results

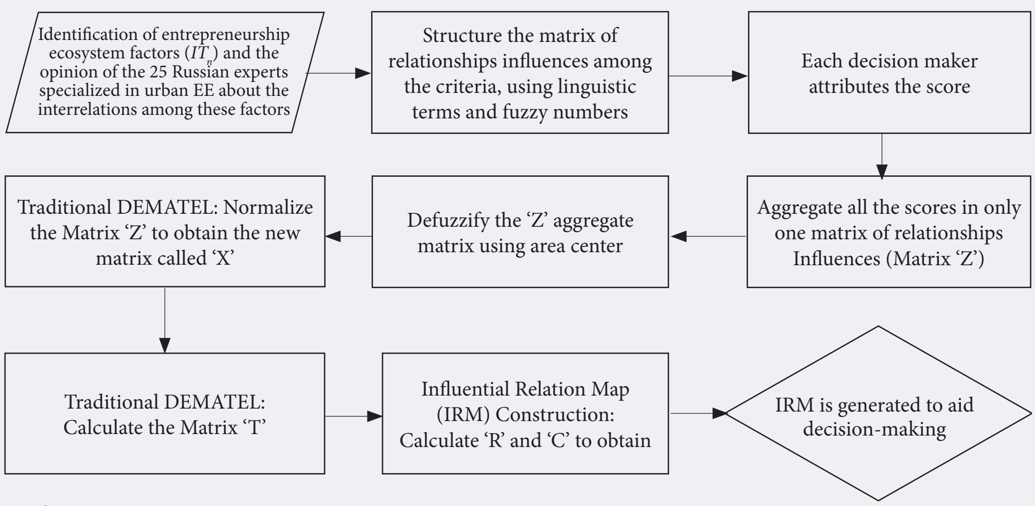
Initially, the variables of the fuzzy DEMATEL model are expressed by an assessment of EE factors and descriptions, as discussed by Stam and van de Ven (2021), as detailed in Table 2, while applying the proposed framework.

As previously stated, empirical data were gathered on seven factors about EEs, categorized as IT_1 through IT_7. A total of 25 specialists in EEs responded to the questionnaire, providing insights into the relationships among these factors and their influence upon EEs within urban settings, with a particular focus on the Russian context.

In this context, we utilize the CFCS (Converting Fuzzy data into Crisp Scores) technique to convert fuzzy assessments into precise values. Fuzzy assessments for these dimensions are presented in Appendices 1 and 2, with their corresponding fuzzy numbers detailed in Table 1.

Applying our proposed method, we present the paired importance and cause-effect outcomes from varied

Figure 2. **Steps for Using the Fuzzy DEMATEL method**



Source: authors.

Table 2. The Influential Factors in EE

Factor	Description
IT_1	Regulatory Environment
IT_2	Infrastructure
IT_3	Market
IT_4	Access to Capital
IT_5	Innovation
IT_6	Human Capital
IT_7	Entrepreneurial Culture

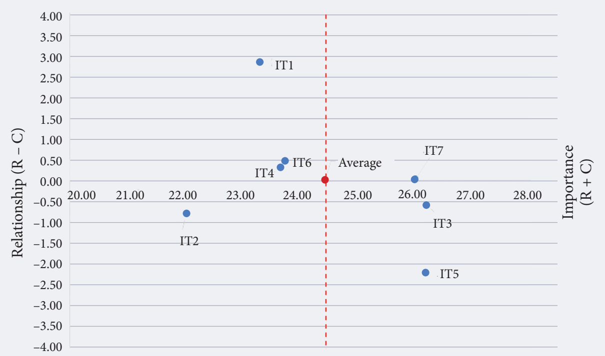
Source: authors.

Table 3. Defuzzified Relationship Matrix Z

	IT_1	IT_2	IT_3	IT_4	IT_5	IT_6	IT_7
IT_1	0.000	0.670	0.663	0.640	0.623	0.557	0.583
IT_2	0.293	0.000	0.513	0.417	0.660	0.630	0.443
IT_3	0.500	0.513	0.000	0.680	0.677	0.550	0.717
IT_4	0.440	0.623	0.687	0.000	0.653	0.467	0.517
IT_5	0.400	0.527	0.720	0.573	0.000	0.427	0.720
IT_6	0.547	0.407	0.553	0.460	0.737	0.000	0.683
IT_7	0.637	0.477	0.687	0.497	0.750	0.650	0.000

Source: authors.

Figure 3. Distribution of the Studied Factors within the Quadrants according to the Degree of Importance and Impact



Source: authors.

Table 4. Relation Matrix T

	IT_1	IT_2	IT_3	IT_4	IT_5	IT_6	IT_7
IT_1	1.461	**1.780**	**2.062**	**1.812**	**2.167**	**1.790**	**1.986**
IT_2	1.263	1.320	1.673	1.453	**1.795**	1.493	1.613
IT_3	1.553	1.716	**1.875**	**1.788**	**2.138**	**1.755**	**1.978**
IT_4	1.445	1.635	**1.908**	1.527	**2.004**	1.633	**1.820**
IT_5	1.441	1.617	**1.918**	1.663	**1.859**	1.628	**1.863**
IT_6	1.483	1.605	**1.900**	1.652	**2.039**	1.536	**1.871**
IT_7	1.605	1.736	**2.062**	1.780	**2.186**	**1.803**	**1.849**

Note: The table highlights represent the values obtained higher than the relation matrix T average of the 1.743. Thus, it is possible to observe how the factors relate to each other, and which are most influenced by the others, as in the case of IT5, IT3 and IT7 which have values greater than the average of the T matrix, representing a significant influence of other factors.

Source: authors.

perspectives, alongside their average performance, in Appendix 3.

Subsequently, all scores were aggregated into a single matrix of relationship influences, called matrix "Z". The aggregation process can be carried out using simple arithmetic averages of the judgments to generate the corresponding fuzzy numbers, as shown in Table 3.

After defuzzification, the traditional DEMATEL steps were followed, employing equations (1-4) and presenting Tables 4 and 5.

In Table 5 and Table 6, it is evident that the regulatory environment factor is the primary driver, followed by human capital, access to capital, and entrepreneurial culture whereas innovation emerges as the most impacted factor. To simplify the assessment, Figure 3 graphically illustrates the cause-and-effect relationship of EE factors in the Russian context.

Analyzing the positions of the most influential and influenceable factors within the EE in the Russian context, based on the results obtained and their positions on the fuzzy DEMATEL interrelationship graph, a detailed interpretation of each factor can be provided, as per the four-quadrant IRM diagram presented and observed in Figure 4. Accordingly, the regulatory environment factor (IT_1) is positioned in Quadrant I, representing a driving factor with a powerful relationship. Consequently, the regulatory environment has a high capacity to influence other factors. The human capital factor (IT_6) also belongs in Quadrant I, functioning as a driving factor and influencing another factor. The access to capital factor (IT_4) is also located in Quadrant I, although with a lower capacity to influence other factors. The entrepreneurial culture (IT_7) is positioned in Quadrant II, identified as a central factor, although

Table 5. Traditional DEMATEL

Factor	R	C	R + C	R – C
IT1 – Regulatory Environment	13.058	10.250	23.308	2.809
IT2 – Infrastructure	10.610	11.409	22.019	-0.799
IT3 – Market	12.804	13.398	26.201	-0.594
IT4 – Access to Capital	11.972	11.675	23.647	0.297
IT5 – Innovation	11.987	14.189	26.176	-2.202
IT6 – Human Capital	12.085	11.636	23.722	0.449
IT7 – Entrepreneurial Culture	13.020	12.980	26.000	0.040

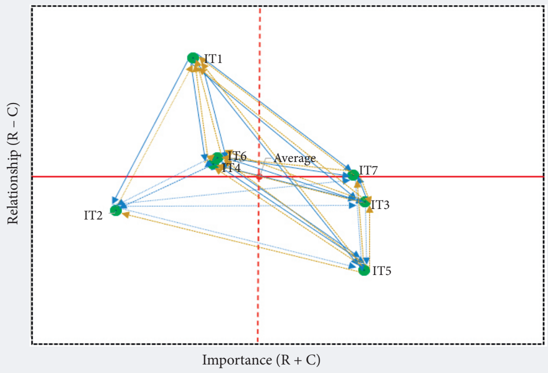
Source: authors.

Table 6. Ordering of Factors

Position	Factor	R – C
1	IT_1	2.809
2	IT_6	0.449
3	IT_4	0.297
4	IT_7	0.040
5	IT_3	-0.594
6	IT_2	-0.799
7	IT_5	-2.202

Source: authors.

Figure 4. **The Relationship and Prominence**



Source: authors.

its value appears minimal compared to the other factors in Quadrant I. Meanwhile, the innovation factor (IT_5) is situated in Quadrant III, presenting itself as highly prominent but with low impact. This indicates how significant innovation is and that it is primarily influenced by other factors. Strategies to improve innovation should consider strengthening the regulatory environment, human capital, access to capital, and entrepreneurial culture, which all influence it directly.

In Figure 4, it is noted that the arrows represent the relationships between the factors. The blue arrows represent the relationship of influence of the factors on others, in which it is possible to observe that the factor IT_1 exerts influence over all factors, as it occupies the first position. The yellow arrows represent the relationship of influence that they receive from other factors; as we can see, the IT_5 factor receives influence from all other factors.

Discussions

In this study, we aimed to understand the main factors that impact the development of EE in the Russian context and how these factors relate to one another using the fuzzy DEMATEL method. As approached in our theoretical background, through the lens of the CAS theory, it is possible to have a holistic and intertwined view regarding the geography and evolution of entrepreneurship as the interplay between the system and its environment (Fredin, Lidén, 2020).

The EE is considered a complex system that involves multiple entities and levels and a diversity of interactions between components, individuals, and social contextual factors (Carter, Pezeshkan, 2023). EEs are also considered open systems with feedback loops characterized by non-linear relationships (Fredin, Lidén, 2020) and the notion of path dependence by incorporating continuity and change (Cloutier, Messeghem, 2022). As a consequence, a large number of scholars consider that EEs are CASs (Fredin, Lidén, 2020; Cloutier, Messeghem, 2022; Carter, Pezeshkan, 2023), mainly because entrepreneurs can be considered agents that affect the development of an EE (Carter, Pezeshkan, 2023), and simultaneous and parallel actions occur, making these EEs pursue self-organizing behavior (Fredin, Lidén, 2020). Yet, systematic assessments about how EE dimensions are interconnected are rare, hampering a thorough examination of the systemic nature of contextual conditions leading to entrepreneurship.

In this respect, self-organization is a process by which agents spontaneously mutually adjust their behavior in a way that allows them to cope with changing internal or external environmental forces (Fredin, Lidén, 2020). During periods of crisis and turbulence, CASs, characterized by internal interactions and feedback processes, learning, and adaptability, serve as controlling mechanisms. Thus, CASs are self-organizing, capable of reaching order without external management (Fredin, Lidén, 2020). In this inquiry, the Russian context illustrates a case in which there are simultaneously incentives for entrepreneurial activities and growth of the country's competitive advantage, while entrepreneurs face significant regulatory and bureaucratic challenges to maintain operational legitimacy. This case, through the lens of the CAS theory, reinforces the influence of the self-organizing behavior of an EE.

In other words, Russian entrepreneurs consistently faced economic instability and turbulence throughout the nation's history. However, nowadays, the government is taking meaningful steps to help entrepreneurs start and run their businesses in a less bureaucratic way. Our results reflected such conditions regarding the regulatory environment as the main factor affecting the Russian EE. Following (Fredin, Lidén, 2020), for example, higher-level regulations are often the result of simple rules and local interactions at the lower level.

Although Russian incentives toward entrepreneurship are focused on innovation (Davidson et al., 2018; Shakib et al., 2023), our analysis indicates that innovation dynamics are the less important factor impacting an EE in this country. We can consider, thus, that for Russian entrepreneurs to be innovative, it is primarily critical to be part of an adaptative system, as it is a factor affected by all ecosystem elements. These systems enabling them to create, replace, develop, restructure, or adapt from within so that they can respond to environmental changes and affect their surroundings.

In the same vein, it is possible to argue that the self-organizing behavior of a Russian EE allows these entrepreneurs to maintain their competitive advantage even in turbulent times, exposing them to a coevolutionary process of identifying, exploiting, and creating new opportunities. In accordance with Carter and Pezeshkan (2023), these dynamics indeed support and explain the emergence of sustainable viability of an enterprise or segment of enterprises in turbulent times.

Based on our findings, this study offers significant contributions. Regarding our methodological approach, we can summarize the main advantages of using the fuzzy DEMATEL method, which employs an innovative approach to handling diffuse assessments. This approach allows for the preservation of more comprehensive information throughout the analysis of relationships among the factors within the EE in the Russian context. As a result, we can analyze the cause-and-effect relationships from various perspectives, taking into account the expertise and knowledge of specialists in EEs. Therefore, the findings indicate that, in crisis conditions, such as those found in Russia, the regulatory environment, human capital, access to capital, and entrepreneurial culture impact innovation in EE more significantly than in more stable economic contexts, thereby corroborating Hypothesis 1 of this study.

Furthermore, the method accounts for the uncertainty in expert information, addressing this practical and inevitable issue in real-world situations, especially during turbulent times. Through this approach, it becomes possible to analyze the interrelations among EE factors in the Russian context, a perspective that has not yet been explored in the literature. Thus, this suggests that, in turbulent times, both the regulatory environment and human capital should be prioritized in terms of actions and public policies to foster innovation in EE, especially in the Russian context.

Additionally, by merging the theoretical characteristics of CAS theory and EE, we could understand a case in a specific context, the Russian one, and the significant influence of a self-organizing behavior (Carter, Pezeshkan, 2023). Thus, managerially, this innovative study contributes to expanding analytical possibilities and decision-making in EEs during turbulent periods. It also facilitates a deeper and more comprehensive exploration of the regulatory environment, human capital, access to capital, entrepreneurial culture to promote greater innovation.

Concluding Remarks

This study contributes to advancing scientific knowledge in its field and provides valuable insights for professionals working with EEs. It introduces an innovative approach to understanding the main factors influencing the development of EEs in cities and elucidates how these factors relate to each other through the application of the fuzzy DEMATEL method. By identifying the regulatory environment, human capital, access to capital, and entrepreneurial culture as the most influential factors in fostering innovation in EEs, this study highlights the effectiveness and robust performance of the proposed approach in turbulent times.

Recognizing the practical application context, it is presumed that there is significant interdependence among these factors within EEs. However, it is important to note that the sampling procedure in this study differs from traditional multivariate analysis, as it involves samples extracted based on expert insights. Additionally, it is essential to observe that this research is limited by its application within a specific geographic and contextual context, namely Russia. Thus, it would be beneficial for future research to explore analogous problems using the fuzzy DEMATEL method and conduct comparative analyses across different countries or models.

The article was prepared within the framework of the Basic Research Program of the HSE University.

References

Aeeni Z., Saeedikiya M. (2019) Complexity Theory in the Advancement of Entrepreneurship Ecosystem Research: Future Research Directions. In: *Eurasian Business Perspectives* (eds. B.M.H. Bilgin, H. Danis, E. Demir, U. Can), Heidelberg, Dordrecht, London, New York: Springer International Publishing, pp. 19–37.

Altshuller M. (2017) Another Forgotten War: The Lack of a Western Response to the Ukrainian Conflict. *Harvard International Review*, 38(S1), 7–8. http://www.jstor.org/stable/26445588

Ansell C., Jarle T., Ogard M. (2017) *Governance in Turbulent Times*, Oxford: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198739517.001.0001

Arici T., Gok M. (2024) Ambiguous Effect of Environmental Turbulence on Innovation and Performance: Analyzing Technology Sectors. *Journal of Innovations in Business and Industry*, 2(1), 13–23. https://doi.org/10.61552/jibi.2024.01.003

Audretsch D.B., Belitski M. (2017) Entrepreneurial ecosystems in cities: Establishing the framework conditions. *The Journal of Technology Transfer*, 42(5), 1030–1051. https://doi.org/10.1007/s10961-016-9473-8

Audretsch D.B., Cunningham J.A., Kuratko D.F., Lehmann E.E., Menter M. (2019) Entrepreneurial ecosystems: Economic, technological, and societal impacts. *The Journal of Technology Transfer*, 44(2), 313–325. https://doi.org/10.1007/s10961-018-9690-4

Bone C. (2016) A complex adaptive systems perspective of forest policy in China. *Technological Forecasting and Social Change*, 112, 138–144. https://doi.org/https://doi.org/10.1016/j.techfore.2016.08.024

Brondoni S.M. (2022) Russian-Ukrainian War, Innovation, Creative Imitation & Sustainable Development. Symphonya. *Emerging Issues in Management*, 1, 4–9. https://doi.org/10.4468/2022.1.02brondoni

Brown R., Mason C. (2017) Looking inside the spiky bits: a critical review and conceptualisation of entrepreneurial ecosystems. *Small Business Economics*, 49(1), 11–30. https://doi.org/10.1007/s11187-017-9865-7

Cantner U., Cunningham J.A., Lehmann E.E., Menter M. (2021) Entrepreneurial ecosystems: A dynamic lifecycle model. *Small Business Economics*, 57(1), 407–423. https://doi.org/10.1007/s11187-020-00316-0

Carter W., Pezeshkan A. (2023) The complexity of entrepreneurial ecosystem evolution and new venture policy: The case of the U.S. commercial space ecosystem. *Technological Forecasting and Social Change*, 192, 122568. https://doi.org/https://doi.org/10.1016/j.techfore.2023.122568

Cloutier L., Messeghem K. (2022) Whirlwind model of entrepreneurial ecosystem path dependence. *Small Business Economics*, 59(2), 611–625. https://doi.org/10.1007/s11187-021-00553-x

Colovic A., Schruoffeneger M. (2022) Entrepreneuring for deprived urban communities: Exploring the role of micro-entrepreneurship. *European Management Review*, 19(3), 450–461. https://doi.org/https://doi.org/10.1111/emre.12458

Daniel L.J., de Villiers Scheepers M.J., Miles M.P., de Klerk S. (2022) Understanding entrepreneurial ecosystems using complex adaptive systems theory: getting the big picture for economic development, practice, and policy. *Entrepreneurship & Regional Development*, 34(9–10), 911–934. https://doi.org/10.1080/08985626.2022.2083691

Fredin S., Lidén A. (2020) Entrepreneurial ecosystems: Towards a systemic approach to entrepreneurship? *Geografisk Tidsskrift – Danish Journal of Geography*, 120(2), 87–97. https://doi.org/10.1080/00167223.2020.1769491

Fuentelsaz L., Maicas J.P., Montero J. (2023) The social status of entrepreneurs: An analysis of informal and formal institutional determinants. *European Management Review*, 12616 (ahead-of-print). https://doi.org/10.1111/emre.12616

Han J., Ruan Y., Wang Y., Zhou H. (2021) Toward a complex adaptive system: The case of the Zhongguancun entrepreneurship ecosystem. *Journal of Business Research*, 128, 537–550. https://doi.org/https://doi.org/10.1016/j.jbusres.2019.11.077

Isenberg D. (2010) How to start an entrepreneurial revolution. *Harvard Business Review*, 88, 40–51.

Khurana I., Dutta D.K., Singh Ghura A. (2022) SMEs and digital transformation during a crisis: The emergence of resilience as a second-order dynamic capability in an entrepreneurial ecosystem. *Journal of Business Research*, 150, 623–641. https://doi.org/https://doi.org/10.1016/j.jbusres.2022.06.048

Kuratko D.F., Fisher G., Bloodgood J.M., Hornsby J.S. (2017) The paradox of new venture legitimation within an entrepreneurial ecosystem. *Small Business Economics*, 49(1), 119–140. https://doi.org/10.1007/s11187-017-9870-x

Malecki E.J. (2018) Entrepreneurship and entrepreneurial ecosystems. *Geography Compass*, 12(3), e12359. https://doi.org/https://doi.org/10.1111/gec3.12359

Moraes G.H.S.M., Schaeffer P.R., Alves A.C., Heaton S. (2025) Exploring a link between faculty intrapreneurship, student entrepreneurship and ecosystem dynamism. *Journal of Entrepreneurship in Emerging Economies*, 17(2), 336–356. https://doi.org/10.1108/JEEE-09-2023-0356

Phillips M.A., Ritala P. (2019) A complex adaptive systems agenda for ecosystem research methodology. *Technological Forecasting and Social Change*, 148, 119739. https://doi.org/10.1016/j.techfore.2019.119739

Rouhani S., Ashrafi A., Afshari S. (2013) Segmenting critical success factors for ERP implementation using an integrated fuzzy AHP and fuzzy DEMATEL approach. *World Applied Sciences Journal,* 22, 1066–1079. https://doi.org/10.5829/idosi.wasj.2013.22.08.631

Roundy P.T., Bradshaw M., Brockman B.K. (2018) The emergence of entrepreneurial ecosystems: A complex adaptive systems approach. *Journal of Business Research*, 86, 1–10. https://doi.org/10.1016/j.jbusres.2018.01.032

Shakib M., Sohag K., Mariev O., Samargandi N., Ferraris A. (2023) Innovation and credit market deepening: Evidence from Russian region. *Journal of Innovation & Knowledge*, 8(3), 100391. https://doi.org/10.1016/j.jik.2023.100391

Shirokova G., Beliaeva T., Manolova T.S. (2022) The Role of Context for Theory Development: Evidence From Entrepreneurship Research on Russia. *Entrepreneurship Theory and Practice*, 47(6), 2384–2418. https://doi.org/10.1177/10422587221138226

Simon H.A. (1962) The Architecture of Complexity. *Proceedings of the American Philosophical Society*, 106(6), 467–482.

Spigel B., Harrison R. (2018) Toward a process theory of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal*, 12(1), 151–168. https://doi.org/10.1002/sej.1268

Stam E. (2015) Entrepreneurial Ecosystems and Regional Policy: A Sympathetic Critique. European Planning Studies, 23(9), 1759–1769. https://doi.org/10.1080/09654313.2015.1061484

Stam E., van de Ven A. (2021) Entrepreneurial ecosystem elements. *Small Business Economics*, 56(2), 809–832. https://doi.org/10.1007/s11187-019-00270-6

Valdez M.E., Richardson J. (2013) Institutional Determinants of Macro-Level Entrepreneurship. *Entrepreneurship Theory and Practice*, 37(5), 1149–1175. https://doi.org/10.1111/etap.12000

Van De Ven H. (1993) The development of an infrastructure for entrepreneurship. *Journal of Business Venturing*, 8(3), 211–230. https://doi.org/10.1016/0883-9026(93)90028-4

Vedula S., Kim P.H. (2019) Gimme shelter or fade away: The impact of regional entrepreneurial ecosystem quality on venture survival. *Industrial and Corporate Change*, 28(4), 827–854. https://doi.org/10.1093/icc/dtz032

Vicentin D.C., Moraes G.H.S.M., Fischer B.B., Campello B.S.C., Prado N.B., Anholon R. (2024) The interdependence between the Entrepreneurial Ecosystem and Entrepreneurial Culture – An analysis with sustainable and traditional entrepreneurs. *Journal of Cleaner Production*, 466, 142821. https://doi.org/10.1016/j.jclepro.2024.142821

Yakovlev A. (2006) The Evolution of Business: State Interaction in Russia: From State Capture to Business Capture? *Europe-Asia Studies*, 58(7), 1033–1056. http://www.jstor.org/stable/20451287

Zhang Z.-X., Wang L., Wang Y.-M., Martínez L. (2023) A novel alpha-level sets based fuzzy DEMATEL method considering experts' hesitant information. *Expert Systems with Applications*, 213, 118925. https://doi.org/10.1016/j.eswa.2022.118925

Zhao X., Xu Y., Vasa L., Shahzad U. (2023) Entrepreneurial ecosystem and urban innovation: Contextual findings in the lens of sustainable development from China. *Technological Forecasting and Social Change*, 191, 122526. https://doi.org/10.1016/j.techfore.2023.122526

Appendix 1. **Fuzzy Relationship Matrix (IT01)**

	IT_1 - IT_1	IT_1 - IT_2	IT_1 - IT_3	IT_1 - IT_4	IT_1 - IT_5	IT_1 - IT_6	IT_1 - IT_7
R1	[0.0,0.0,0.0]	[0.25,0.5,0.75]	[0.75,1,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.75,1,1]
R2	[0.0,0.0,0.0]	[0.75,1,1]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]
R3	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]
R4	[0.0,0.0,0.0]	[0.0,0.25,0.5]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0,0.25,0.5]
R5	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.75,1,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]
R6	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]
R7	[0.0,0.0,0.0]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]
R8	[0.0,0.0,0.0]	[0.25,0.5,0.75]	[0.75,1,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.25,0.5,0.75]
R9	[0.0,0.0,0.0]	[0.75,1,1]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]
R10	[0.0,0.0,0.0]	[0.75,1,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.75,1,1]	[0.25,0.5,0.75]
R11	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.0,0.25,0.5]	[0.0,0.25,0.5]	[0.25,0.5,0.75]
R12	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.75,1,1]	[0.25,0.5,0.75]	[0.0,0.25,0.5]
R13	[0.0,0.0,0.0]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]
R14	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.75,1,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]
R15	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]
R16	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]
R17	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0.0,0.25,0.5]
R18	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]
R19	[0.0,0.0,0.0]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.75,1,1]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0.0,0.25,0.5]
R20	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]
R21	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]
R22	[0.0,0.0,0.0]	[0.0,0.0,0.25]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]
R23	[0.0,0.0,0.0]	[0.5,0.75,1]	[0.75,1,1]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.75,1,1]
R24	[0.0,0.0,0.0]	[0.75,1,1]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]
R25	[0.0,0.0,0.0]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0.0,0.0,0.25]	[0.25,0.5,0.75]	[0.25,0.5,0.75]
Aggregate	[0.0,0.0,0.0]	[0.44,0.68,0.89]	[0.43,0.68,0.88]	[0.40,0.65,0.87]	[0.39,0.63,0.85]	[0.32,0.56,0.79]	[0.35,0.59,0.81]

Source: authors.

Appendix 2. **Fuzzy Relationship Matrix (IT07)**

	IT_1 - IT_1	IT_1 - IT_2	IT_1 - IT_3	IT_1 - IT_4	IT_1 - IT_5	IT_1 - IT_6	IT_1 - IT_7
R1	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.75,1,1]	[0.0,0.0,0.25]	[0.75,1,1]	[0.75,1,1]	[0.0,0.0,0.0]
R2	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.75,1,1]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R3	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.75,1,1]	[0.75,1,1]	[0.0,0.0,0.0]
R4	[0.0,0.0,0.25]	[0.0,0.0,0.25]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.0,0.0]
R5	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R6	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.0,0.0]
R7	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.0,0.0]
R8	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.75,1,1]	[0.0,0.25,0.5]	[0.75,1,1]	[0.75,1,1]	[0.0,0.0,0.0]
R9	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.75,1,1]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R10	[0.75,1,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.75,1,1]	[0.0,0.0,0.0]
R11	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.0,0.25,0.5]	[0.0,0.25,0.5]	[0.0,0.25,0.5]	[0.0,0.0,0.0]
R12	[0.75,1,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.0,0.0,0.0]
R13	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.0,0.0]
R14	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R15	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R16	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.0,0.0]
R17	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.75,1,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.0,0.0,0.0]
R18	[0.0,0.25,0.5]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.75,1,1]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R19	[0.5,0.75,1]	[0.5,0.75,1]	[0.75,1,1]	[0.75,1,1]	[0.75,1,1]	[0.75,1,1]	[0.0,0.0,0.0]
R20	[0.25,0.5,0.75]	[0.0,0.0,0.25]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R21	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.5,0.75,1]	[0.0,0.0,0.0]
R22	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R23	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.25,0.5,0.75]	[0.5,0.75,1]	[0.0,0.0,0.0]
R24	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.5,0.75,1]	[0.0,0.25,0.5]	[0.75,1,1]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
R25	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.25,0.5,0.75]	[0.0,0.0,0.0]
Aggregate	[0.40,0.64,0.87]	[0.24,0.47,0.72]	[0.46,0.70,0.91]	[0.27,0.49,0.73]	[0.53,0.78,0.94]	[0.42,0.67,0.86]	[0.0,0.0,0.0]

Source: authors.

Appendix 3. **Fuzzy Relationship Aggregated Matrix**

	IT_1	IT_2	IT_3	IT_4	IT_5	IT_6	IT_7
IT_1	[0.0,0.0,0.0]	[0.44,0.68,0.89]	[0.43,0.68,0.88]	[0.4,0.65,0.87]	[0.39,0.63,0.85]	[0.32,0.56,0.79]	[0.35,0.59,0.81]
IT_2	[0.09,0.27,0.52]	[0.0,0.0,0.0]	[0.28,0.52,0.74]	[0.2,0.41,0.64]	[0.43,0.66,0.89]	[0.39,0.63,0.87]	[0.23,0.43,0.67]
IT_3	[0.26,0.51,0.73]	[0.27,0.52,0.75]	[0.0,0.0,0.0]	[0.44,0.69,0.91]	[0.44,0.69,0.9]	[0.31,0.56,0.78]	[0.49,0.73,0.93]
IT_4	[0.24,0.43,0.65]	[0.38,0.63,0.86]	[0.46,0.71,0.89]	[0.0,0.0,0.0]	[0.43,0.67,0.86]	[0.23,0.46,0.71]	[0.27,0.52,0.76]
IT_5	[0.16,0.4,0.64]	[0.29,0.53,0.76]	[0.49,0.74,0.93]	[0.34,0.58,0.8]	[0.0,0.0,0.0]	[0.2,0.42,0.66]	[0.5,0.75,0.91]
IT_6	[0.32,0.55,0.77]	[0.19,0.4,0.63]	[0.31,0.56,0.79]	[0.23,0.46,0.69]	[0.51,0.76,0.94]	[0.0,0.0,0.0]	[0.55,0.8,0.933]
IT_7	[0.4,0.64,0.87]	[0.24,0.47,0.72]	[0.45,0.7,0.91]	[0.27,0.49,0.73]	[0.53,0.78,0.94]	[0.42,0.67,0.86]	[0.0,0.0,0.0]

Source: authors.